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'Words, words, words'

'What do you read, my lord?' inquired Polonius. 'Words, words, words,' replied Hamlet. Scientists may find entertainment for their leisure in following the princely example, for nowhere is the catholicity of science so manifest as in its vocabulary. The fascination of etymology lies in the associations it evokes, and even when the authenticity of a particular derivation is dubious it may serve to awaken interest or pleasure. It is likely that no philologist would stake his reputation on the suggestion that 'sulphur' is of Sanskrit origin, yet *sulva-ari* is the Sanskrit for copper-enemy, and what more appropriate name could be desired for element 16? Of soda, the dictionaries cautiously say no more than that it is medieval Latin of doubtful etymology, but anyone who has had recourse to sodium bicarbonate for the relief of a bilious attack may well favour its derivation from the Arabic word for a headache, *suda'*.

Sodium sounds plebeian against the euphoniously patrician potassium, but potassium is a *parvenu* unable to conceal its social climb from pot-ash. Yet potash is not to be despised: we may recall that no less a figure than Benjamin Franklin busied himself in encouraging the manufacture of potash in England and America. No-one has put forward any convincing etymology of gold—which may be cognate with yellow—but copper conjures up visions of the mimosa-scented island of Cyprus and of the Cyprian goddess rising from the sea in a cockle-shell. A fairy-tale atmosphere comes with cobalt, associated with the mischievous German gnomes or kobolds, and it would be a pity to destroy the atmosphere by inopportunely recollecting that the Assyrians of 600 B.C. employed a mineral called *kibaltu* in the manufacture of blue glass.

One could wish to be able to associate thulium with the Abbaye de Thélème rather than with the land described by Pytheas as surrounded by an impalpable mass like a jellyfish, and Rabelais would have found a man after his own heart in his chemist-contemporary Paracelsus. It does not require much imagination to picture Paracelsus, booted and spurred and well wined, lying on his bed and carelessly coining the word zinc or arbitrarily transferring *al-kuhl* from stibnite to ethanol. He would have appreciated the humorist who derived *antimoine* from the sad effect of tartar emetic upon a monkish community.

Many names of minerals and plants, and of mineral and plant products, carry us far across the world and far back into time. Indigo and ebony are said to be of Greek origin; if so, it can be only a coincidence that corresponding ancient Egyptian words are *n-tinkon* and *hebene*. Marcasite is the Assyrian *marhashi*, for the same mineral, and sapphire the Assyrian *sipru* or scratching stone—sapphire is next to diamond on Mohs's scale. Benzene takes us ultimately to Java, for it derives from the Arabic *luban jawi*, the Javanese resin, known to the west as gum benzoin. Quinine whisks us to the other side of the world, for it comes from the Peruvian *kina*, tree-bark; and zoologists may travel north to Mexico, to find the Aztec axolotl (servant of water) and quetzal. Naphtha is said to be Persian but is actually older, stemming from the Assyrian *naptu*, bitumen; on the other hand, Persia should have narcissus, for the Greek *narkissos* seems more likely to have sprung from the Persian *nargess* than from the *narke* suggested by Pliny and Plutarch. Litmus was imported from the Arabic as early as 1502, but that was a century later than zenith, realgar, alkali, borage, and cipher. Artichoke is a much travelled word. It started in Arabia as *al-kharshuf*, became transformed in Italy to *articiocco* and in France to *artichaut*, anglicized itself as artichoke, and migrated back to Arabia as *ardi shufi*, in which guise it figures in modern Arabic dictionaries. Jerusalem in artichoke connection is, as Dr Opimian put it, 'a palpable misnomer' for the Italian *girasole*; it is as misleading as the name Regulus for the star α-Leonis, which is not a petty Latin king but an Arabic lion's paw (*rijlu'l-asad*).

Kelp has proved an insoluble enigma to etymologists. It appears first—apparently from nowhere—in 1387, in John de Trevisa's translation of Higden's *Polychronicon*: 'As culpes of the see waggeth with the water.' It seems to have no linguistic affiliations, but, since many plant names were being imported from the Orient at that period, we may perhaps see a possible origin for it in the Arabic *qilf*, meaning rind or peelings. 'Peelings of the sea' would be an appropriate term for *Laminaria* and other seaweeds.

Names of the elements are usually self-explanatory, but samarium is deceptive: instead of coming from Samaria it derives from the mineral samarskite, itself called after one Colonel Samarski and representing the sole recorded fact about him. Samarski thus shares with the mineralogist Gadolin the honour of being one of the only two men after

whom natural elements have been named—unless, indeed, Lecoq de Boisbaudran had the pretty conceit of naming gallium after himself instead of after his country.

It would be pleasant to wander further in the attractive realm of real and fanciful etymologies, but there is another—and more serious—aspect of the scientific vocabulary. With the growth of science there grew also the need for terminologies that should be at once concise and precise. This need was first acutely felt in the eighteenth century, especially in the science of chemistry. It found voice in the person of Guyton de Morveau, and was further expressed by Lavoisier, in his prefatory memoir to the *Méthode de Nomenclature Chimique* (1787) drawn up by himself, de Morveau, Berthollet, and Fourcroy. He observes that there are three things to distinguish in every physical science: the series of facts that constitute the science, the ideas that recall the facts, and the words that express the ideas. The word must evoke the idea, the idea must depict the fact: they are but three impressions of the same seal. The perfect chemical nomenclature would render ideas and facts in their exact verity, without suppression and, more particularly, without addition; it ought to be nothing more than a faithful mirror. It is obvious that the language of chemistry up to that time had not been formed on those principles; indeed, it could not have been. Moreover, some chemical expressions were introduced by the alchemists with an exactly opposite intention, namely to obscure knowledge rather than to reveal it; thus a pelican was an apparatus for distillation, and *caput mortuum* signified the residue left in the still. More ridiculous still were oil of vitriol, oil of tartar by deliquescence, butter of arsenic, flowers of zinc, liver of sulphur, sugar of lead, etc., which (as Dumas remarked later) made one think that chemists borrowed their language from the kitchen.

We know that Lavoisier's attempt to reform chemical nomenclature was ultimately successful—but we know also that new problems have arisen, and that no satisfactory solution to them has been found. Increasing specialization of knowledge has inevitably sharpened the appetite for economy of expression, with the result that the technical language of specialists in one branch of science is as unintelligible to specialists in other branches as Ogham would be to a Patagonian. What, for example, is the botanist likely to gather from such physical terms as gamma-decay, antineutrino, kicksorter, and (incredibly) cutie pie? Or the physicist from the botanist's homoiochlamydeous, monochasium, strophiole, and suffruticose? Or either of them from the chemist's chelation, heteropolyacids, interstitial hydrides, and glucopyranosidofructofuranoside? Physicists, botanists, and chemists are of course no more prone to jargon than workers in other fields of science, and it is true that all these arcane scientific dialects serve the very useful purpose of enabling information to be exchanged quickly, briefly, and accurately between those who are familiar with them.

At the same time, and even though modern scientific language is certainly not intended to keep knowledge secret, it is very regrettable that ideas which in themselves would probably be perfectly intelligible to the average scientist, of every persuasion, should be so expressed as to give no clue to their character. Specialization in science works in two ways, which appear at first sight to be diametrically opposed. In the first place, the specialist tends to concentrate on a narrow topic, and is inclined to neglect what goes on outside his own particular field, but, in the second place, it happens more and more frequently that discoveries in one branch of science prove to have great significance for others. There is therefore an urgent need, not for less specialization, but for the ready dissemination of knowledge from each scientific study to all the others. Here, jargon is the great barrier. How great it is, editors of such journals as ENDEAVOUR probably realize better than most. It has often been—indeed, regularly is—our experience that an article written by an acknowledged authority on his subject, and pellucidly clear to his fellow-workers, may be so much gibberish to equally accomplished scientists of other interests. This unfortunate circumstance is not wholly unavoidable. However important it may be that workers in the same field should be able to save time by using a cryptic argot among themselves, it is at least as important that they should also give an intelligible account of their work to scientists in general. It need not always be a detailed account, but it should be clear and accurate enough to enable workers in other branches to estimate whether it describes results which might have a bearing upon their own investigations. In any case, scientists possess as much curiosity as other men, and share their weakness for wanting to know what is going on over the garden wall. If specialization (as we have been told so many times that we weary of it) is knowing more and more about less and less, it should not necessarily entail the penalty of having to know less and less about more and more.

The micro-analysis of the inert gases

F. A. PANETH

This article forms an appropriate sequel to M. W. Travers' account of Sir William Ramsay's life and work (ENDEAVOUR, II, 126, 1952), for it describes modern methods of analysing very tiny quantities of the inert gases and the discoveries made as a result. In 1936, for example, they made possible the first isolation of a synthetic element—helium—in measurable quantity. Micro-methods have also been used for identifying the radioactive isotopes of xenon and krypton resulting from uranium fission, for estimating the age of iron meteorites, and for investigating changes in the composition of the stratosphere.

The history of chemistry provides many examples of the well known fact that scientific progress frequently depends on the refinement of laboratory methods. We may even say that chemistry in the modern sense of the word was the direct outcome of the technique of handling gases as developed by Hales, Scheele, Priestley, Watt, and Cavendish; for the fundamental laws of chemistry could be recognized only when, after centuries of melting solids and distilling liquids, the theoretically simpler but experimentally much more difficult study of gases had got under way. Some of the most fundamental laws of physics could be found by rather primitive experiments, e.g. the weighing of a golden crown submerged in water or the observation of the swing of a chandelier; but even in a fairly well equipped chemical laboratory the most talented workers were groping in the dark until the initial difficulties of gas analysis had been overcome. It is equally obvious that improvements in gas-analytical technique often marked the beginning of new periods; we have only to remember the impetus organic chemistry received from Liebig's methods of combustion and absorption, or biological chemistry from the introduction of the micro-analytical technique by Pregl.

In a similar way, the discovery and study of the inert gases was essential for the recognition of fundamental laws of theoretical chemistry concerning the natural system of the elements and the theory of valency. A kind of micro-analysis was necessary to discover these so-called rare gases; today large quantities of them can be obtained, but there is still need for a micro-technique, for it is the possibility of operating with them in smaller and smaller quantities that opens the way towards the solution of a number of important problems. We shall describe in the following pages modern methods of handling and measuring minute amounts of the inert gases, and some of the scientific results achieved thereby.

1. EARLIER STUDIES ON INERT GASES

The purely chemical part of Ramsay's famous work on inert gases was essentially finished when, during the years 1895–1900, mostly in collaboration with Travers, he had discovered, and studied the properties of, helium, neon, krypton, and xenon; this followed the pioneer work in 1894 of Lord Rayleigh and himself on argon [1]. In the course of these researches, entirely new methods and apparatus for dealing with comparatively small quantities of the inert gases had been developed, and a few years later this delicate technique became very welcome in the new science of radioactivity.

After the establishment of the theory of radioactive disintegration by Rutherford and Soddy, Rutherford's extensive studies on the nature of α-rays, and Ramsay's discovery of helium in radioactive minerals, there was a high probability that α-rays consisted of charged helium atoms, and it seemed feasible to show experimentally that, after having lost the charges, these rays formed the gas helium. 'At that time there was only one place in the world where that could be done. It was in Sir William Ramsay's laboratory in London' [2]. The investigation which Ramsay and Soddy [3] carried out there in 1903 proved for the first time the production of helium gas by radioactive substances ; it was of outstanding importance in firmly establishing the theory of radioactive disintegration, and has today an honoured place in the history of science.

Another confirmation of a prediction made in Ramsay's laboratory was that of the approximate atomic weight of radium emanation, or radon as it is now called. This investigation, undertaken by Whytlaw-Gray and Ramsay [4] in 1910,

involved the weighing on a micro-balance of a quantity of only 0·1 cubic millimetre of a gas which, owing to its intense radio-activity, must have caused almost insurmountable difficulties in the way of obtaining trustworthy results. The values for the atomic weight finally accepted in this *tour de force* varied in different experiments from 218 to 227. They could serve to confirm the more exact figure 222·4, which in those days was generally recognized on the basis of Mme Curie's atomic-weight determination of radium, the radioactive-disintegration theory, and Debierne's excellent effusion experiments [5]; it was, however, hardly justifiable that, after finishing this investigation, Ramsay declared that only now had radium emanation been established as a new chemical element, and claimed the right to give it a name, niton—which, by the way, was not accepted.

Less successful were attempts by Ramsay and his school to prove that radioactive rays were able to transmute the ordinary stable elements. It must be admitted that in trying to do this he displayed what Rutherford [6] later called his 'characteristic instinct for choosing the best line of attack,' but it was just here that the limitations of his accuracy in experimenting, and the pitfalls in the current methods of the micro-analysis of the inert gases to be discussed later, became obvious. Ramsay first claimed to have converted, by the application of radon, oxygen into neon, copper into lithium, and thorium into carbon. These statements were refuted by several more careful workers, but Ramsay could not be induced to withdraw them. On the contrary, when, a little later in his laboratory, Collie and Patterson believed they had found evidence that electric discharges can produce helium and neon, he considered this as an indirect confirmation of his old claims.

Collie and Patterson's paper [7] introduced a rather unfortunate period of uncertainty into the science of elementary transmutations. One has to remember that in those days theory was still of little help to decide whether or not bombardment by cathode rays could transmute measurable quantities of ordinary elements. Such experiments were under way in Rutherford's laboratory, as mentioned by him in his Bakerian lecture [8], and, shortly after the announcement of Collie and Patterson's results, J. J. Thomson [9] published a paper in which similar observations were described, and considered as an indication that some non-radioactive elements 'made attempts to expel atoms of helium' which were assisted by the cathode rays. It was thus obvious that the correctness of Collie and Patterson's claim could be tested only by further experiment. A repetition of their experiments under improved conditions by Merton [10], Egerton [11], Strutt [12], and others gave negative results, but Ramsay, Collie, and their collaborators did not yield, and R. W. Riding and E. C. C. Baly [13] believed that they had discovered the source of the helium in the discharge tubes to be the nitrogen present.

A study of these and other papers of this period is not only interesting from a historical point of view, but rewarding on account of the number of useful occasional observations and remarks they contain. We should like specially to mention the many very valuable contributions to the micro-analysis of helium made by R. J. Strutt (the fourth Baron Rayleigh), which in those days did not perhaps get all the credit they deserved, overshadowed as they were by the fame of Ramsay's laboratory. It was somewhat unfortunate that, thanks to the fundamental work done earlier by Ramsay and his collaborators, their announcements were considered by the general public as authoritative in all questions concerning the inert gases, even at a time when they no longer deserved this reputation. When, years later, we tried to perfect the methods of the analysis of inert gases, we found in Strutt's papers a number of most helpful hints, and hardly any statement at all which we could not fully confirm. The only drawback seems to have been that, working in a private laboratory, he did not have at his disposal equipment as good as most university laboratories possessed.[1]

II. DEVELOPMENT OF THE METHODS SINCE 1925

In 1913 the author was introduced to the methods of the analysis of rare gases, as practised by the Ramsay school, during a stay in the physical-chemical laboratory of the University of Glasgow, and he is greatly indebted to Frederick Soddy for the instruction received from him personally. Near the end of his stay, he performed some experiments to test the correctness of Collie and Patterson's claims, but had to leave before

[1] After succeeding to the title in 1919, Lord Rayleigh worked at Terling in his father's laboratory; that he himself was quite aware of the limitations imposed thereby can be seen from his remarks about his father's researches [14]. In the thirties, when the author worked at the Imperial College in London, Lord Rayleigh came two or three times to see his apparatus and borrowed special devices, but later returned them unused, as being too complicated to be applied in his own laboratory.

unambiguous results were achieved; it was his intention to pursue this line in the Radium Institute in Vienna—in those days the best-equipped laboratory for radioactive research—but war broke out before preparations were finished, and it was not until 1925, while he was working in the chemical laboratory of Berlin University, that the original plan could be put into effect. By then, the possibility of artificial transmutation of elements by bombardment with α-particles had been demonstrated by Rutherford, but on so small a scale that only physical methods which permitted the detection of single atomic processes, such as the fluorescent screen or electric counters, could be used. There was, however, some hope that, with considerable increase in the sensitivity of their methods, it might become possible for chemists to join in the fascinating study of artificial atomic transmutation. With this aim in mind, it seemed necessary first of all to clear up the contradictions which still existed in the literature about the possibility of helium formation by electric discharges, as described by Collie and his co-workers, and by J. J. Thomson.

The time seemed specially favourable to make a fresh start with the micro-analysis of the inert gases, since during the previous few years high-vacuum technique had been greatly improved by the introduction of new pumping devices. Up to about 1904, the only method for obtaining a high vacuum was the use of a Töpler pump or some of its modifications; the tediousness of the process has been frequently described [15]. By the twenties, or even earlier, however, it was possible to obtain a high vacuum by the much more effective and rapidly working rotary and diffusion pumps. This is not the place to describe in detail the strides made possible by these technical advances, but it should be emphasized that the progress we were able to make beyond the work of earlier workers was to a large extent due to the benefit we derived from the availability of the modern high-vacuum pumps.

The first task was to decide how far the old experiments were reliable and, if not, where the sources of error came in. We followed the directions of most of the research workers who had claimed to have produced helium or neon by electric discharges. When all necessary precautions were taken, we could never observe either of these gases, and we could explain from which sources they had come in the old experiments. It had been suspected [10] that stopcocks could not safely be used in such delicate experiments. We found that this fear is unfounded, and that any number of carefully ground and greased stopcocks can be used, still without any leakage of atmospheric air whatsoever. The chief source of error was found to lie in the permeability of glass to atmospheric helium and, to a much lesser extent, atmospheric neon [16]. The observation of Ramsay [17], who discovered ample quantities of helium in old X-ray tubes made of glass, an observation quoted in support of Collie's claims, was due merely to the high temperature the glass acquires while the tube is running. On analysing the gas content of an electric bulb after a few days' burning we found a similar amount of helium, but if the bulb had been burning under water the effect was completely suppressed. Diffusion through hot glass gives easily detectable quantities of helium. In smaller amounts, helium may be found in such experiments as Collie and Patterson's even if the glass remains cool, because when it has previously been exposed to the atmosphere it is saturated with helium, which is given off into the vacuum of the apparatus. A small fraction of this dissolved helium is not released into the vacuum even if the glass is heated, but can be driven out if the heating takes place not in a vacuum but in the presence of hydrogen. This last effect is so small that it became noticeable only after our methods of detecting helium had reached their present refinement, and for a few months we believed that in this instance some new helium had actually been formed; but we soon traced its appearance to this unexpected, and not yet thoroughly studied, displacement effect by hydrogen. After we had noticed this last source of error, we could always obtain perfect blank experiments, and could increase the sensitivity of the helium analysis by several orders of magnitude. The smallest quantity dealt with before (by Strutt [12]) was 5×10^{-7} cc (NTP); by 1928 we could detect 10^{-9} to 10^{-10} cc [18].

All the older experiments (as far as they were not falsified simply by the elementary mistake of an air leakage), including those of J. J. Thomson, could now be accounted for by the fact that the solubility of helium in glass had come into play; other explanations favoured previously, for instance the occlusion of helium in the metal electrodes [6], or in the mirror produced by their sputtering, played at most a very minor part (see the very competent report on our first experiments by Egerton [19]).

During the last quarter of a century we have tried further to develop the micro-analysis of

inert gases to the perfection demanded by the nature of various scientific problems. Without mentioning the earlier stages, we shall give here a brief description of the apparatus in its present form.

III. THE DURHAM APPARATUS

The apparatus for the micro-analysis of the inert gases which, with minor alterations, has now been in use for three or four years in the Londonderry laboratory for radio-chemistry at Durham, is meant to serve for work on very different problems: measurement of helium produced by γ-rays in beryllium for an absolute neutron-standard; determination of the curie value of 1 g of radium; geological age determinations by the helium and argon methods on iron and stone meteorites, minerals, and rocks; analysis of stratospheric air; and so on. It thus contains many parts which are not necessary for each and every determination, and to represent them all in one diagram would be confusing; we have, therefore, made separate sketches of sections of the apparatus, and in discussing the application of our method we shall indicate which sections have to be used. The reader must then imagine these sections—which are all drawn to scale—to be joined as they actually are in the real apparatus. I am much indebted to my collaborator, B. S. Wiborg, for drafting the sketches.

Some special devices, e.g. the palladium furnace for burning the last traces of hydrogen; the barium furnace for the argon, krypton, and xenon analysis; the fractionating column for the separation of helium and neon; the Pirani gauges for the measurement of these gases; and the vessels for air-free dissolution, have been developed in the course of our investigations and have proved their usefulness, but the mere fact of their employment does not in itself ensure the success of our methods. It must be understood that the highest accuracy can be achieved only by very careful attention to dozens of trivial details, as for instance the correct greasing of the stopcocks, complete removal of gas from the charcoal and the glass connections, purity of the mercury, temperature control, etc. It would need much more space than is available here to explain all these details—which, indeed, can be much better learned on the spot by watching the operations performed. Just as Frederick Soddy learnt the older methods directly from Ramsay, and the author had the privilege of practising them in Soddy's laboratory, a number of younger workers in the laboratories of Berlin, Königsberg, London, and Durham have handed on their experiences in an unbroken tradition during the last twenty-five years, frequently adding essential improvements. Their names appear in the publications from these laboratories quoted at the end of this article. One of our co-workers in Königsberg, W. D. Urry, later built a similar apparatus in the Massachusetts Institute of Technology [20], whence the technique of helium measurements for the purpose of geological age determinations has spread to laboratories in Washington [21] and Toronto [22]; but the whole range of methods, and also their greatest refinement, can at present be seen only at Durham, where explanations are always gladly given to interested colleagues. We are going to describe here only the principles of the methods; it is hoped, however, that the sketches accompanying the text will convey a good deal more information to all those who are familiar with the older gas-analytical technique. The references to the literature indicate where the piece of apparatus shown in the illustration (or, in some cases, an earlier model of it) has been described.

The whole Durham apparatus, in duplicate, is housed in a simple hut (figure 1). As a very desirable improvement we would recommend an air-conditioning system; in our hut, high temperatures in summer cause difficulties with the greased stopcocks.

Helium

The main research problems in which the determination of very small quantities of helium is desired are geological age determinations, natural and artificial transmutations of elements, and analyses of stratospheric air.

It is obvious that, for age determinations according to the helium method, it is essential to set free the total helium which has accumulated in a solid substance. If it is a rock or a mineral, the standard method, introduced by Strutt, is heating. We have only occasionally studied the geological ages of rocks [23], and only slightly improved this method of liberating helium (or radon). It has been very thoroughly investigated in the Massachusetts Institute of Technology; a description of a very efficient furnace to be used in connection with the vacuum apparatus can be found in papers by R. D. Evans [24].

Heating is not sufficient if the helium to be collected is occluded in a metal. This explains why Strutt [25], who treated an iron meteorite in the same way as other materials, was misled into believing that it contained hardly any helium.

FIGURE 1 – *Hut in which the Durham apparatus is housed.*

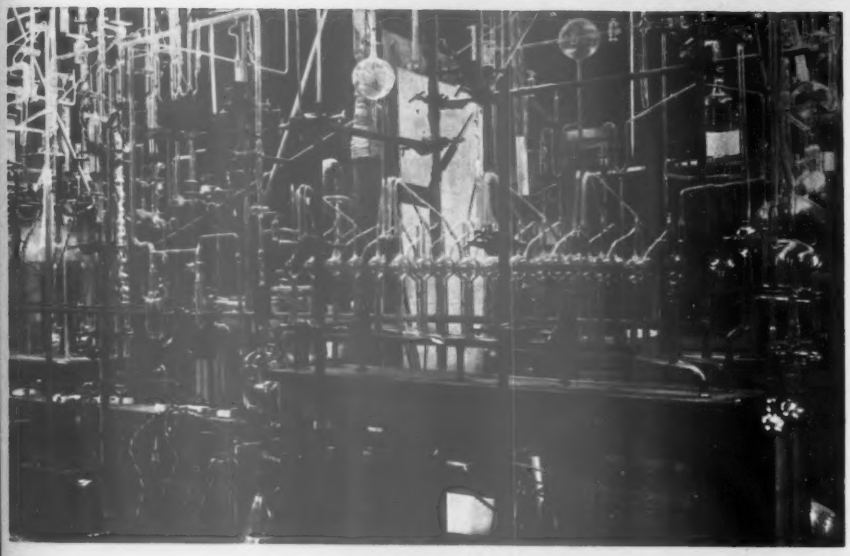


FIGURE 2 – *Part of the Durham apparatus. In the foreground is the fractionating column for helium and neon analyses.*

FIGURE 3 – *Part of the Durham apparatus. On the bench, a steel cylinder with stratospheric air; in the foreground, the barium furnace for argon determination.*

Since, on the other hand, this helium-tightness makes iron meteorites much safer objects for the application of the helium method than rocks or minerals, and since, moreover, their ages are for cosmological reasons of special interest, we have concentrated on them. In order to release the helium, the iron has to be dissolved; if this is done in acids (figure 4*h*) large quantities of hydrogen are evolved, which have to be burnt with oxygen in a specially constructed vessel (figures 4*j* and 5) [26]. In order to avoid this complication we found it useful to dissolve the metal in an oxidizing copper chloride solution [27]. In each case, the last traces of hydrogen can best be removed by burning them in an excess of oxygen on palladium as a catalyst (figure 4*b*) [28].

A very similar experimental problem presents itself when, in connection with the establishment of a neutron standard, the helium produced by γ-rays in beryllium has to be investigated (figure 4*e*) [26].

The helium so collected from meteorites should be free from neon, and, after this has been confirmed by a spectroscopic observation, the helium can be measured directly in a Pirani gauge (figure 4*c*) [29].[1] The spectroscopic observation, however, always involves the risk of small quantities of helium getting lost, through the electric discharge, and whenever we have to deal with very small quantities of helium, or are aiming at the very highest accuracy, we avoid the spectroscopic observation and pass the helium through a fractionating column in which charcoal tubes are cooled in liquid nitrogen (figures 2 and 4*c*). We know exactly in which fraction helium ought to appear, and can pass this fraction into the Pirani gauge with complete confidence that it contains no other gas. Since, however, this fractionating column is more difficult to construct and to work than most other parts of our apparatus, and is unnecessary if quantities of helium of not less than 10^{-6} cc have to be measured, we think it advisable also to show in a sketch an apparatus for the helium determination in metals which uses the spectroscopic test (figure 5). On the left of this figure are indicated the two alternative methods of dissolving, in acid and in copper chloride solutions.

When the problem is the determination of helium in the atmosphere, its separation from neon by a fractionating column has of course to be performed. The column just mentioned was conceived and constructed for this purpose by E. Glückauf [30], and is constantly used in a slightly modified form (figure 4*c*) [31] in our helium and neon determinations. The Pirani gauge in which the helium is finally measured has been constructed in this laboratory in various different forms [29]; the latest and most satisfactory one is shown in figure 6.

[1] The Pirani gauge acts by measuring the rate at which heat is lost by a hot wire in the gas.

Neon

The determination of neon follows the same lines as that of helium. The Pirani gauge must, of course, be specially calibrated for neon. Its sensitivity for this gas is somewhat lower than for helium [32], but is still very satisfactory. Quantities of the order of 10^{-6} cc of both gases can be measured with an accuracy of approximately one per cent.

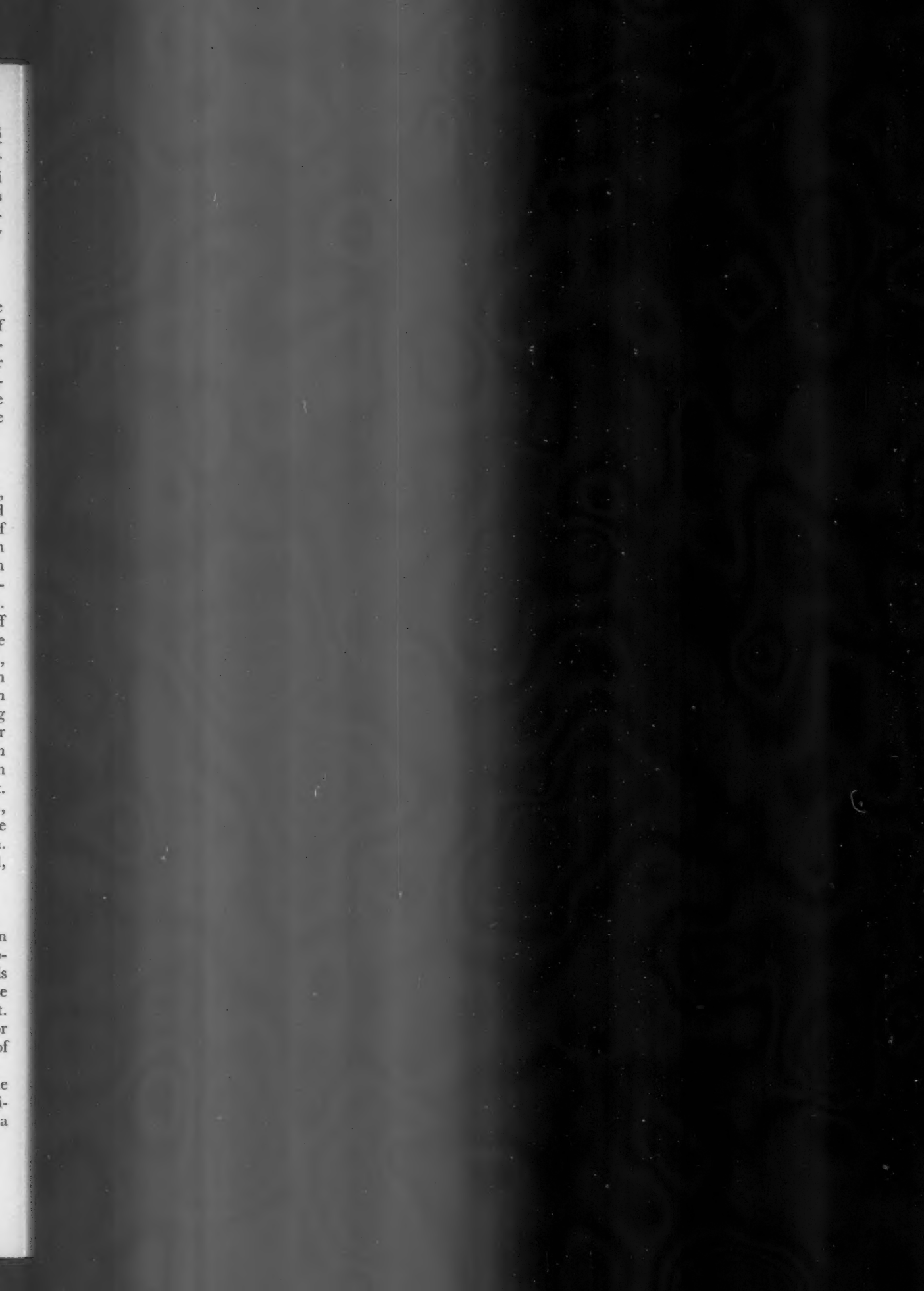
Argon

Argon, as well as the three heavier inert gases, can be completely adsorbed on charcoal at liquid nitrogen temperature, which makes the handling of them in many respects simpler than that of helium and neon. The whole group of the inert gases can be separated from all the reacting gases in calcium or barium furnaces (figures 3 and 4*f*) [33, 34]. Helium and neon, if present, can be pumped off while the three heavier members of the group are adsorbed, and the separation of argon, krypton, and xenon from each other can be achieved in an apparatus somewhat similar to the helium/neon fractionating column mentioned above, but using higher temperatures for the cooling bath [33]. For the separation of argon from krypton and xenon the charcoal should be kept at about — 78° C. In one complete fractionation only about 95 per cent. of the argon is removed; the remaining 5 per cent., together with krypton and xenon, has to be returned to the apparatus and separated again. Then 99·95 per cent. of the argon can be collected, with 1 per cent. of krypton.

Krypton and xenon

The separation of these two gases from argon has been described above; the separation of krypton from xenon can be effected if the charcoal is held at a temperature of about — 20° C. Here again, in the first set of operations only 95 per cent. of the krypton is obtained in a pure state, and for a practically complete separation a repetition of the process is necessary [33].

In the problems which interested us, the amounts of argon, krypton, and xenon were sufficient to be measured, after separation, in a McLeod gauge.



Radon and thoron

Owing to their radioactivity, these two isotopes of element 86 can be measured in much smaller quantities than can the stable inert gases. It should, of course, not be forgotten that some of the active isotopes of the other members of the inert-gas group offer the same advantage; for instance, the active isotopes of krypton and xenon which are produced by the fission of uranium. The methods to be recommended for the determination of radon and thoron depend on their quantities; we were interested in developing methods of the highest sensitivity because, in connection with the geological age determinations of meteorites, we had to analyse the uranium and thorium present in iron meteorites, and one of the best ways of doing this is by measurement of the equilibrium quantities of radon and thoron. Since the iron meteorites contain less uranium and thorium than any terrestrial rock or mineral, we found that the usual methods for radon and thoron estimation were not suitable. Our procedure consisted usually in preparing a solution of intermediate products (radium for the uranium series, and thorium-X for the thorium series), and in transferring the radon and thoron formed therein to a suitable ionization chamber. Owing to the very short half-life of thoron, this has to be done in a constant stream (figure 7, upper half), while radon is allowed to accumulate up to nearly the equilibrium quantity and is then quantitatively transferred into the ionization chamber (figure 7, lower half) [27]. The disintegrations occurring in the chamber are measured by means of a linear pulse amplifier.

These methods made it possible for us to determine quantities of 10^{-8} g of uranium or thorium per gram of meteorite; but the limits of error were still considerable, owing to the impossibility of avoiding some background effects. For the analysis of the uranium and thorium in iron meteorites we have, therefore, lately abandoned the radon and thoron method in favour of a determination of uranium by a fluorescence method, and the measurement of thorium-C in a scintillation counter. The radon and thoron methods described above will, however, still be found very useful if uranium and thorium in terrestrial minerals have to be measured.

IV. RECENT RESEARCHES ON MICRO-QUANTITIES OF INERT GASES

The methods described here have been successfully applied during the last few years to a number of problems.

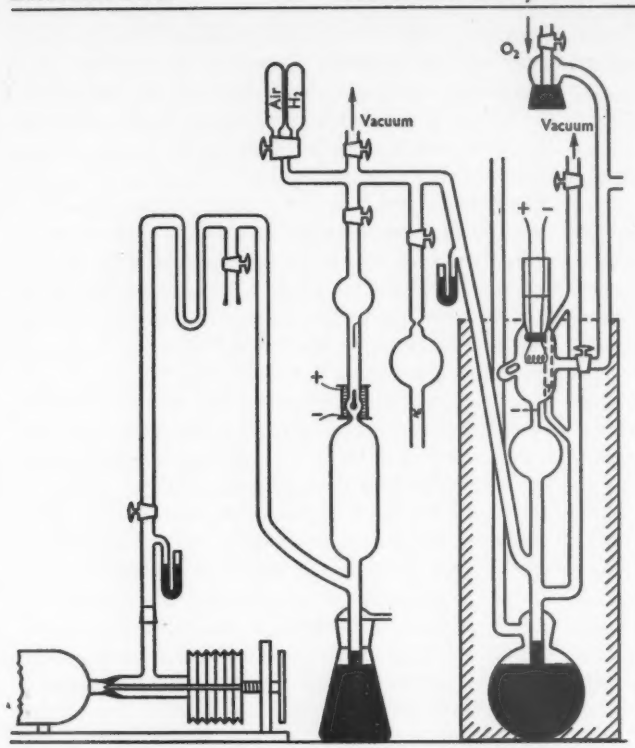
First, we tried by chemical methods to prove the reality of artificial transmutations. The original aim—to demonstrate spectroscopically the production of hydrogen from nitrogen by bombardment with α-particles—could not be achieved [35]; and though it is a favourable circumstance that in this process the minute amounts of hydrogen are produced in the presence of a large surplus of helium, which favours the spectroscopic test, the sensitivity of the detection of hydrogen in helium is not as high as stated in a paper by Collie and Ramsay [36]. They were probably misled by the much larger quantities of hydrogen escaping from the glass of their apparatus.

It was not until after other means of transmutation had been found that the quantities formed seemed to be just large enough for chemical handling. We thought it feasible to produce sufficient helium by the bombardment of boron with neutrons from a fairly strong radium-beryllium source, and this attempt succeeded; we were able for the first time to isolate in a pure state an artificially produced element, to identify it spectroscopically, and to measure its quantity, thus fulfilling in a sense the fond dreams of the alchemists [28]. A similar experiment was shortly afterwards carried out with beryllium [26]. Here the methods of the physicists could not decide whether the product of disintegration by γ-rays was a beryllium isotope of mass 8, or two helium atoms; the results of our measurement of helium decided in favour of the second alternative.

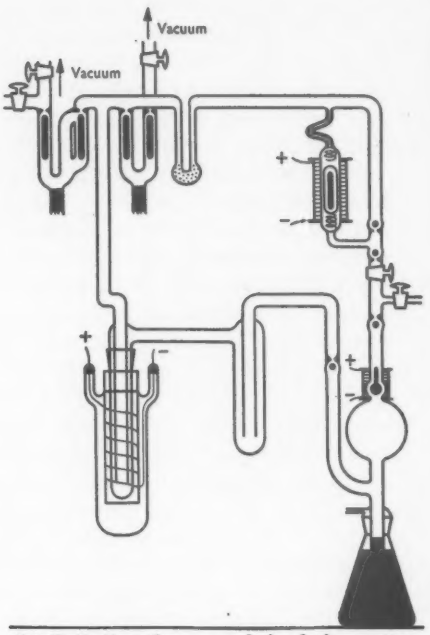
The accuracy with which helium can be collected and determined in this experiment offers good hope for using this method in the construction of an absolute neutron standard [37]. Experiments on these lines are in progress.

Since the building of uranium piles, much larger quantities of matter have been transmuted, and weighable amounts of many nuclides have been produced, but the traces of newly formed elements or isotopes are often still so small that micro-methods have to be applied. For special reasons it seemed important to get information about the radioactive isotopes of xenon and krypton originating from the fission of uranium. An application of our methods made it possible to collect each of these gases separately in quantities of 10^{-3} cc for a full mass-spectroscopic examination [33, 38].

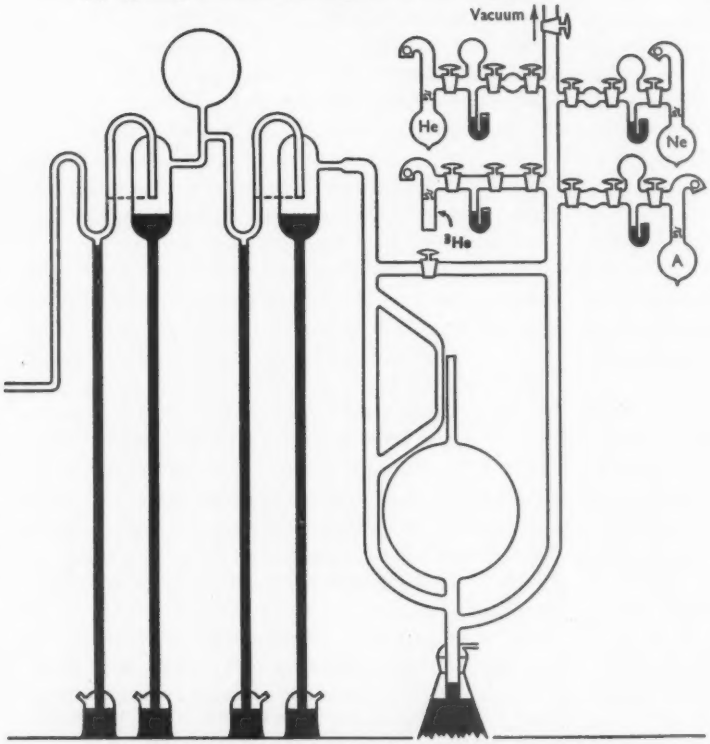
Another problem where micro-methods seem to offer a solution is the precise measurement of the number of α-particles emitted per second from one gram of radium. This constant has been determined several times, and by different methods,



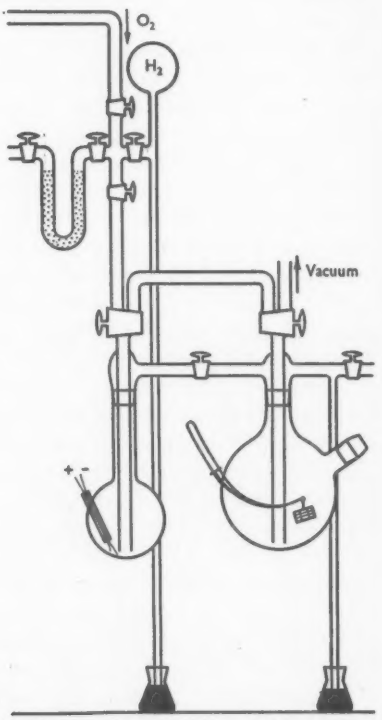
(a) *Opening mechanism, storage bulb, and air pipette.*



(b) *Palladium furnace and circulating system.*

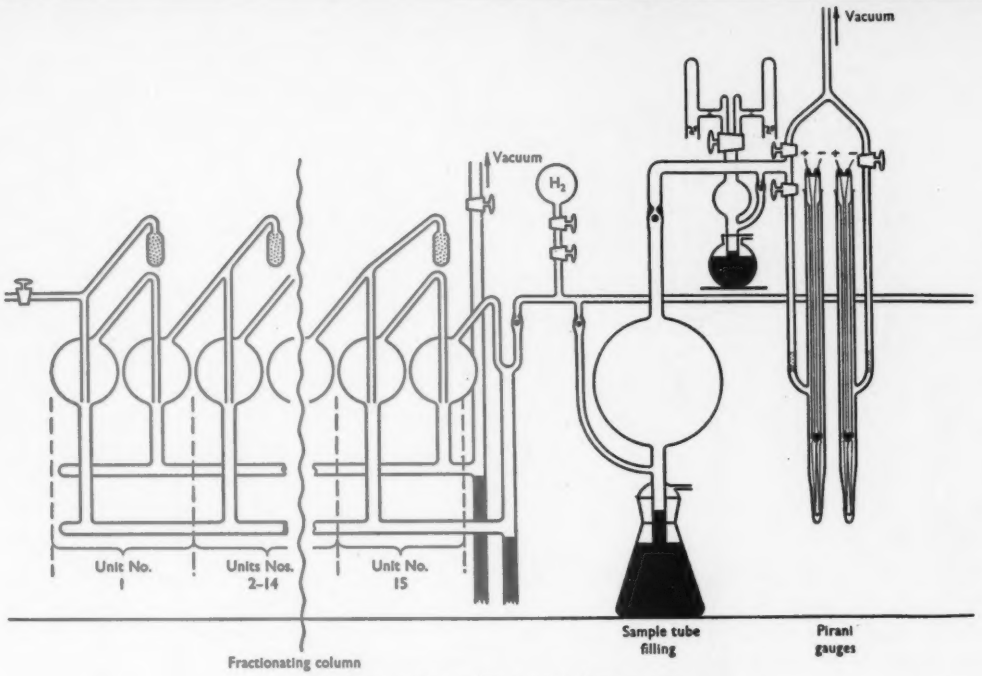


(d) *McLeod gauge for calibration and expansion system.*

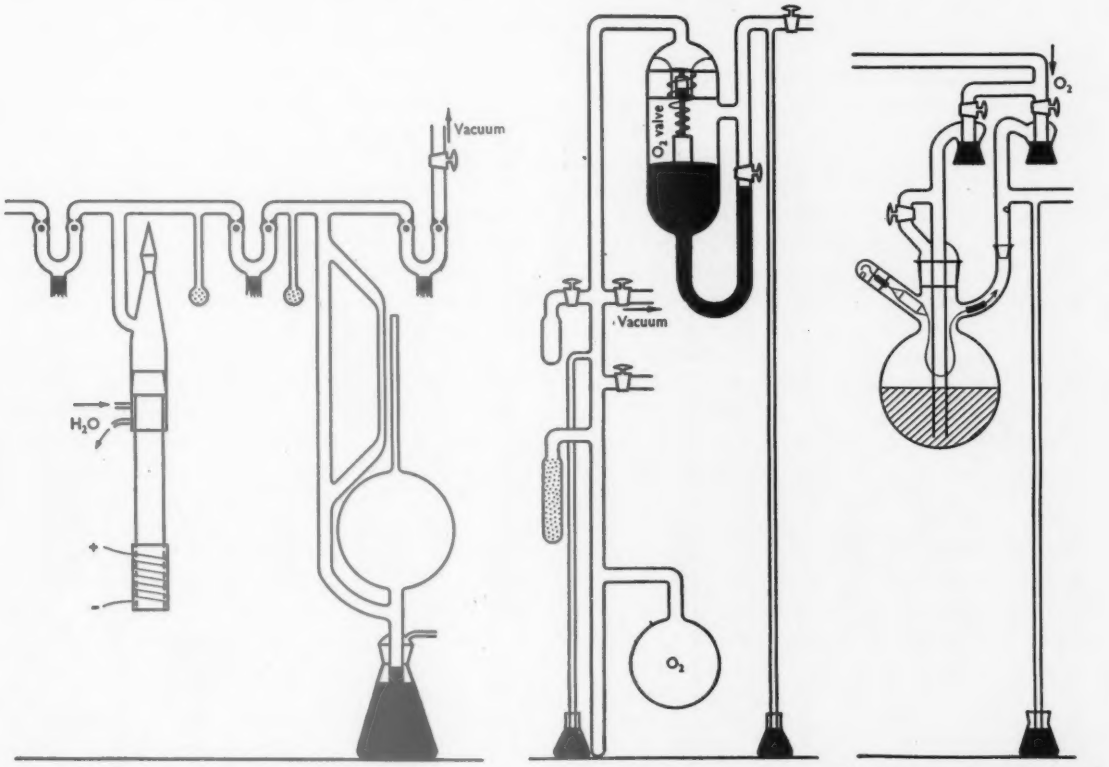


(e) *Metal-dissolving vessel and hydrogen reservoir.*

FIGURE 4 – *The Durham apparatus, represented in sections.*

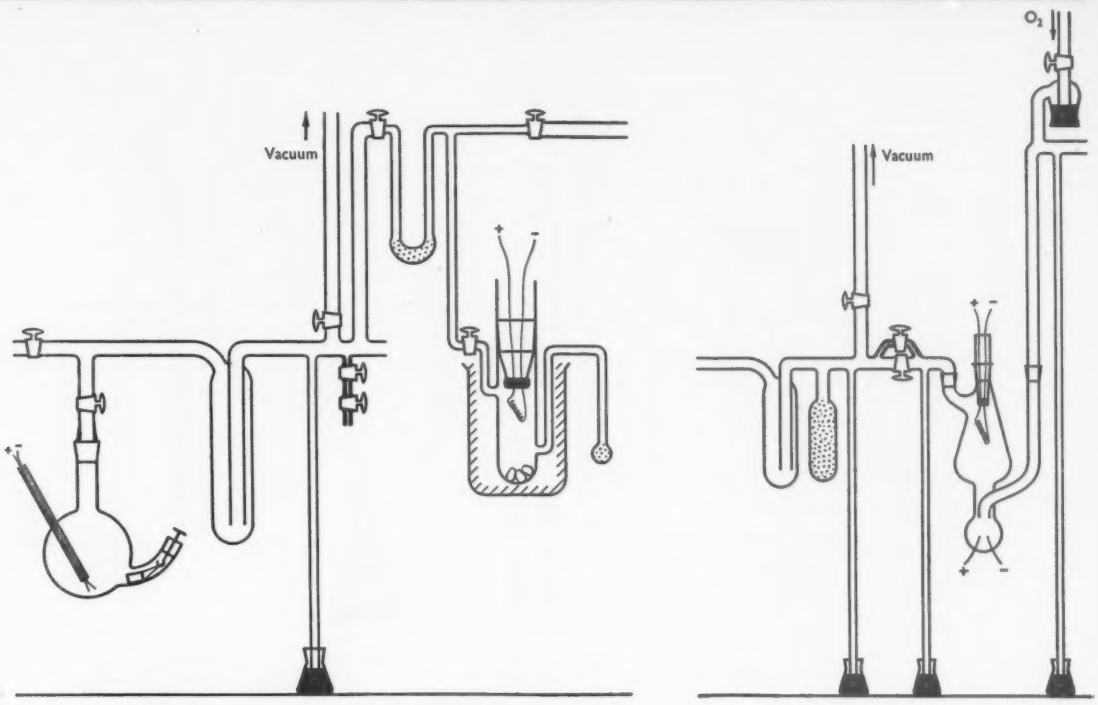


(c) *Fractionating column and Pirani gauges.*



(f) *Barium furnace and McLeod gauge.* (g) *Oxygen reservoir.* (h) *Meteorite-dissolving vessel.*

FIGURE 4 (continued)



(i) *Salt-dissolving vessel and gas-purification system.* (j) *Hydrogen burner.*

FIGURE 4 (continued)

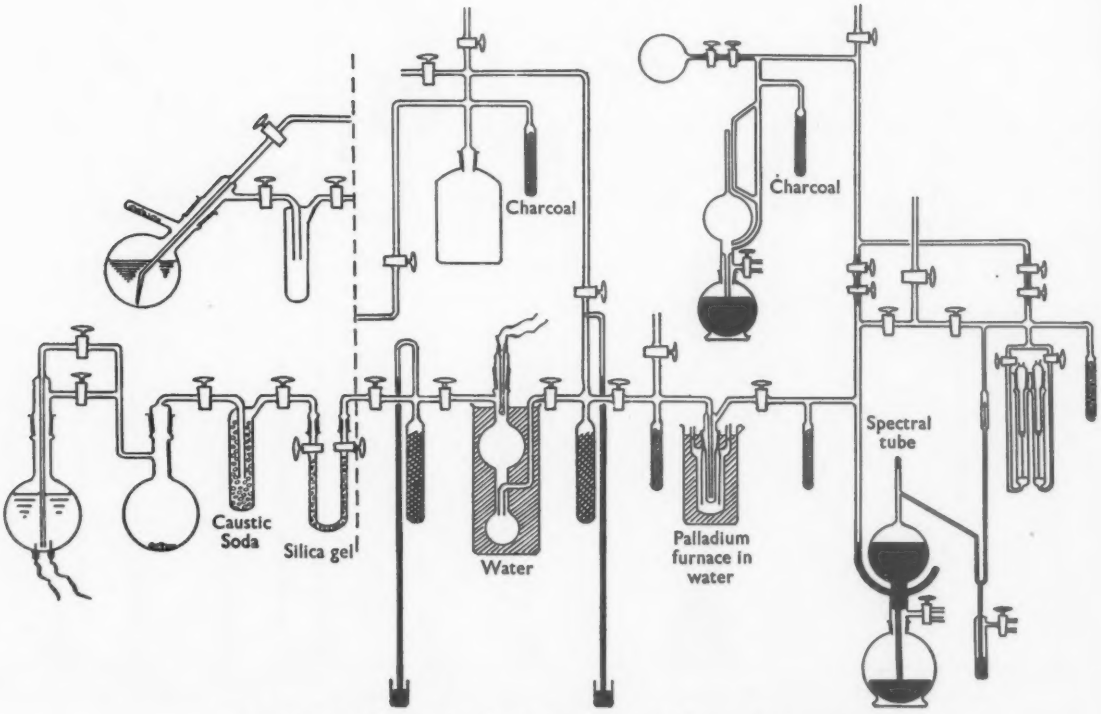


FIGURE 5 – *Apparatus for the measurement of helium in meteorites.*

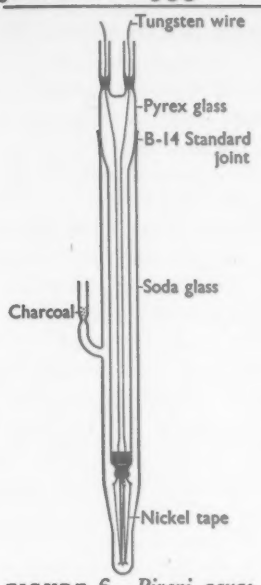


FIGURE 6 – *Pirani gauge.*

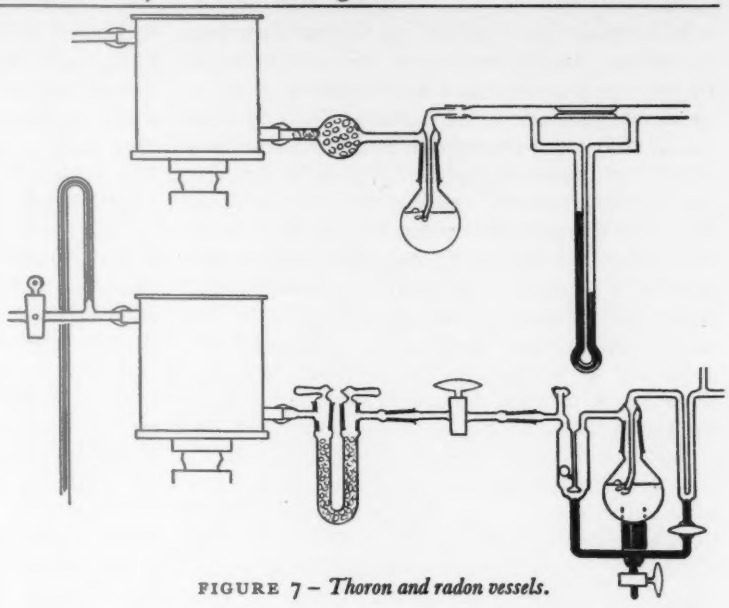


FIGURE 7 – *Thoron and radon vessels.*

but the results are not concordant. Until recently, the figure of $3{\cdot}7 \times 10^{10}$ was considered as well established, but in 1946 the value $3{\cdot}6 \times 10^{10}$ was found [39] by a method using more modern counting devices, though in other respects not clearly superior. A decision between these two figures is all the more important as recently the curie has been re-defined [40]; originally it meant the quantity of radon in equilibrium with one gram of radium, but now it is defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is $3{\cdot}700 \times 10^{10}$. Since the two international radium standards of Paris and Vienna, as well as the many national standards in various countries, are based on the weight of radium, the very unsatisfactory situation has now arisen that the exact values of these standards cannot be expressed in the fundamental unit of radioactivity, the curie, until the number of α-particles emitted by one gram of radium is known with certainty. While formerly it was considered a success when an approximate agreement was found between the volume of helium collected and the number of α-particles counted, it now seems possible to use the measurement of the small helium quantities for a decision between the two values of α-particle counts [41].

As soon as the new method for the micro-determination of helium appeared satisfactory, we tried to use it for an attempt to investigate the age of iron meteorites [42]. In those days, two ways of radioactive age determinations were used: the lead method and the helium method. The latter was due mainly to the efforts of Strutt, but he could never overcome the difficulty that, during geological ages, part of the helium was likely to have escaped from the uranium and thorium minerals investigated. As previously stated, iron meteorites are a much more reliable material, since it can be proved that the helium is here much more firmly bound than in any mineral or rock and cannot be driven out even by strong heat.

Shortly after we had published our first results on meteorites in which use was made of the increased sensitivity in detecting and measuring helium, A. Holmes conceived the idea that the helium method of age determination need no longer be restricted to strongly radioactive materials, like the uranium and thorium minerals analysed so far, but could now be applied to ordinary rocks which, owing to the much smaller amount of helium occluded, were more likely to retain it quantitatively [43]. This idea has been at least partly justified, and many attempts at age determination of rocks have been carried out in various laboratories. Very thorough work is being done by P. M. Hurley at the Massachusetts Institute of Technology [44], and it can be said that the difficulties still remaining are no longer due to the small quantities of helium to be measured, but to the varying retentivity of minerals for helium and the heterogeneity of the distribution of uranium and thorium in rocks which consist of very different minerals.

Both these uncertainties are absent with iron meteorites. If well developed, iron meteorites are single crystals which can be considered as completely helium-tight, and whose chemical composition does not vary appreciably over distances of at least several decimetres. The only difficulty is their extremely low uranium and thorium content, which has been mentioned before, but our methods for radon and thoron determination are sensitive enough to find these values with a fair degree of accuracy, while the precision of the helium measurement is more than sufficient. Only a fraction of a gram of the precious meteorite material is needed for a helium analysis—a further advantage of our micro-methods; in earlier estimations hundreds of grams were used [25].

During the last twenty-five years or so we have collected figures for the helium content of more than fifty iron meteorites, with rather surprising results [27]. Some meteorites solidified less than a million years ago, while others seemed to give values up to seven thousand million years, thus exceeding the greatest age found for any terrestrial rock by a factor of between two and three. While the low ages can be explained by various assumptions, the high ages appeared rather unlikely, because they would indicate that at the time of the formation of the meteorites the less stable uranium isotope U 235 had been considerably more abundant than the more stable U 238, and also because the higher age figures come uncomfortably near the limit often assumed today for the age of the universe.

The solution seems to lie in the fact that not all the helium in meteorites is of radioactive origin, but that some of it has been produced by the intense cosmic rays to which they have been exposed during their flight through space [45]. To test this idea, we have recently collected helium from five iron meteorites in quantities of 10^{-6} to 10^{-4} cc, and have examined its isotopic composition [46]. The helium consisted of up to 24 per cent. of helium 3, thus proving the cosmic ray origin of a very considerable fraction of the total helium. For comparison, it may be mentioned that in the helium from radioactive minerals and from gas-wells, helium 3 is present only to the order of 10^{-5} per cent., and in atmospheric helium to the order of 10^{-4} per cent. More analyses of meteorites are necessary before it will be possible to unravel exactly the contributions made to their helium content by radioactivity and by cosmic rays, but the way now seems clear to a really reliable age determination. This should help to clarify our still very obscure ideas about the origin of the solar system.

Another interesting aspect of the discovery of so much helium 3 in meteorites is that it opens an approach to the study of the intensity of cosmic rays in localities outside the magnetic field of the earth, and in times long past [47].

Similar to the helium method of age determination is the newly developed argon method. It has already been applied by a technique modelled after ours by Smits and Gentner [48], and is being used in this laboratory also.

The new micro-methods have found quite a different application in studies of the upper atmosphere. On theoretical grounds, it was long ago predicted that at great heights the light gases of the atmosphere should be enriched in proportion to the heavier ones. Nearly all the laboratories which obtained samples of stratospheric air for analysis confined themselves to the determination of the oxygen. Omitting various older statements, which were certainly erroneous, it must be recorded that fairly recent analyses of stratosphere air from heights between 18 and 29 km seemed to indicate that its oxygen content was diminished, in accordance with theoretical predictions. In point of fact, the choice of oxygen as the test gas is most unfortunate; obviously it is more simply determined than all the rest of the atmospheric gases, but at the same time it is the one most likely to have been partly lost by chemical reactions. We believe that this has always been the reason for the low figures found. It is, on the other hand, very unlikely that atmospheric nitrogen would react with the vessel in which the sample had been collected, and this possibility is completely excluded in the case of the inert gases. It seemed to us, therefore, much safer to test the ratio of the inert gases to nitrogen. If the predicted gravitational separation has taken place, we must expect that the ratio of helium and neon to nitrogen will be increased, and the ratio of argon to nitrogen decreased.

After extensive preliminary work in which we established the constancy of the helium content in atmospheric air all over the world [49] we were fortunate enough to receive stratospheric samples collected over New Mexico by means of rockets [50]. Up to 60 km no change in the percentage composition of the atmosphere was found [51], but above that limit, for the first time and in four independent samples, the predicted change in the ratio of inert gases to nitrogen could be established [31].

In view of the great interest which meteorologists and physicists take today in the question of the upper atmosphere, it is hoped that this collaboration with the American rocket research team at the University of Michigan will be continued, and extended to still greater heights. The steel cylinders of 8 litres capacity (figure 3) recovered from rocket flights to heights of about 65 km contained at NTP no more than about a cubic centimetre of air, and from 100 km we do not expect to receive more than about one-tenth of a cubic centimetre. We nevertheless hope to be able to determine the nitrogen, helium, neon, and argon content in these samples with sufficient accuracy for the measurement of the gravitational shift in the composition of the stratosphere occurring at these extreme heights.

We have no doubt that other research problems in which mastery of the micro-analysis of rare gases is imperative will offer themselves in the future. Many, indeed, are already becoming apparent, and the usefulness of these micro-methods will certainly continue to increase both in extent and in variety.

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The Zoological Society of London

L. HARRISON MATTHEWS

The Zoological Society of London was founded in 1826, largely as the result of the energy and initiative of Sir Stamford Raffles, Governor of Singapore. In 1829, being firmly established, it obtained its royal charter from King George IV, and entered upon the long and successful career that has continued until the present day. Like many others of its kind, it started purely as a learned society—the objects laid down were the advancement of zoology and animal physiology and the introduction of new animal species—but its evolution has taken it to a unique position very different from that occupied by sister societies.

One of the ways in which the Zoological Society of London fulfilled the objects of its charter was by the accumulation of a collection of animals both living and dead, for it maintained a museum of preserved animals as well as a menagerie of living ones. The museum was dispersed about 1851, all the more valuable specimens being presented to the British Museum (Natural History), now at South Kensington, London.

At first, the menagerie was a private collection to which only fellows of the Society were admitted. It aroused so much interest, however, that even the admission of the friends of fellows was insufficient to satisfy the demand, and the general public was admitted, on the payment of a fee, on two days a week. Even this proved not to be enough, and increasing privileges have been granted up to the present day, when the public is denied entry only on Sunday mornings.

Without deliberate intention, therefore, the Society's menagerie has become a national institution, known among the general public as just 'the Zoo.' Indeed, many people, perhaps the majority, are under the mistaken impression that it is supported out of public funds; this is very far from the truth, for it is entirely maintained by the subscriptions of fellows and the charge for admission made to the public.

The activities of the Society on the scientific side, although less known, are as flourishing as those more generally familiar. The Society's house in Regent's Park contains a fine meeting-hall in which the scientific meetings are held, and also a splendid library covering many fields of biology, running to over 100,000 volumes. Scientific meetings are held monthly during eight months of the year; at them, the results of the latest researches in a great many branches of zoology are laid before the fellows. These researches are published in the journals of the Society, the 'Proceedings' and the 'Transactions of the Zoological Society of London,' which have been published in an unbroken series since 1832 and 1835 respectively. The Society is justifiably proud of these fine publications, in which communications bearing names famous in zoology for more than a century are to be found. The staff of the Society includes several qualified scientists, whose task is to pursue researches on the animals in the Society's collection. Many zoologists, both past and present, who have reached the highest ranks in biological science, started their careers with the Society. It has also sponsored or contributed to the expenses of many scientific expeditions to all parts of the world, and has benefited by their results not only in additions to the menagerie but in scientific communications for its publications.

The Zoo occupies thirty-five acres of Regent's Park, and is intersected by the Regent's Canal and a roadway known as the outer circle. The gardens are thus divided into three parts: the north, middle, and main gardens. The north and middle gardens are connected by two bridges over the Regent's Canal, and the middle and main gardens by two tunnels beneath the outer circle. The gardens have been developed from time to time during the last century, but little now remains of any of the original buildings. The camel house, with the clock tower above it, is the chief remnant of the past, although it has been much restored: the terrace above the bear cages is also a relic of the original lay-out. For the rest, the houses have been rebuilt and remodelled so many times that nothing recognizable remains of the original gardens. At no time was a consistent plan of development followed, and the buildings therefore show considerable lack of uniformity. A redevelopment plan has, however, now been devised, and this, if used as a guide, will result in the Zoo of the future being much more homogeneous and

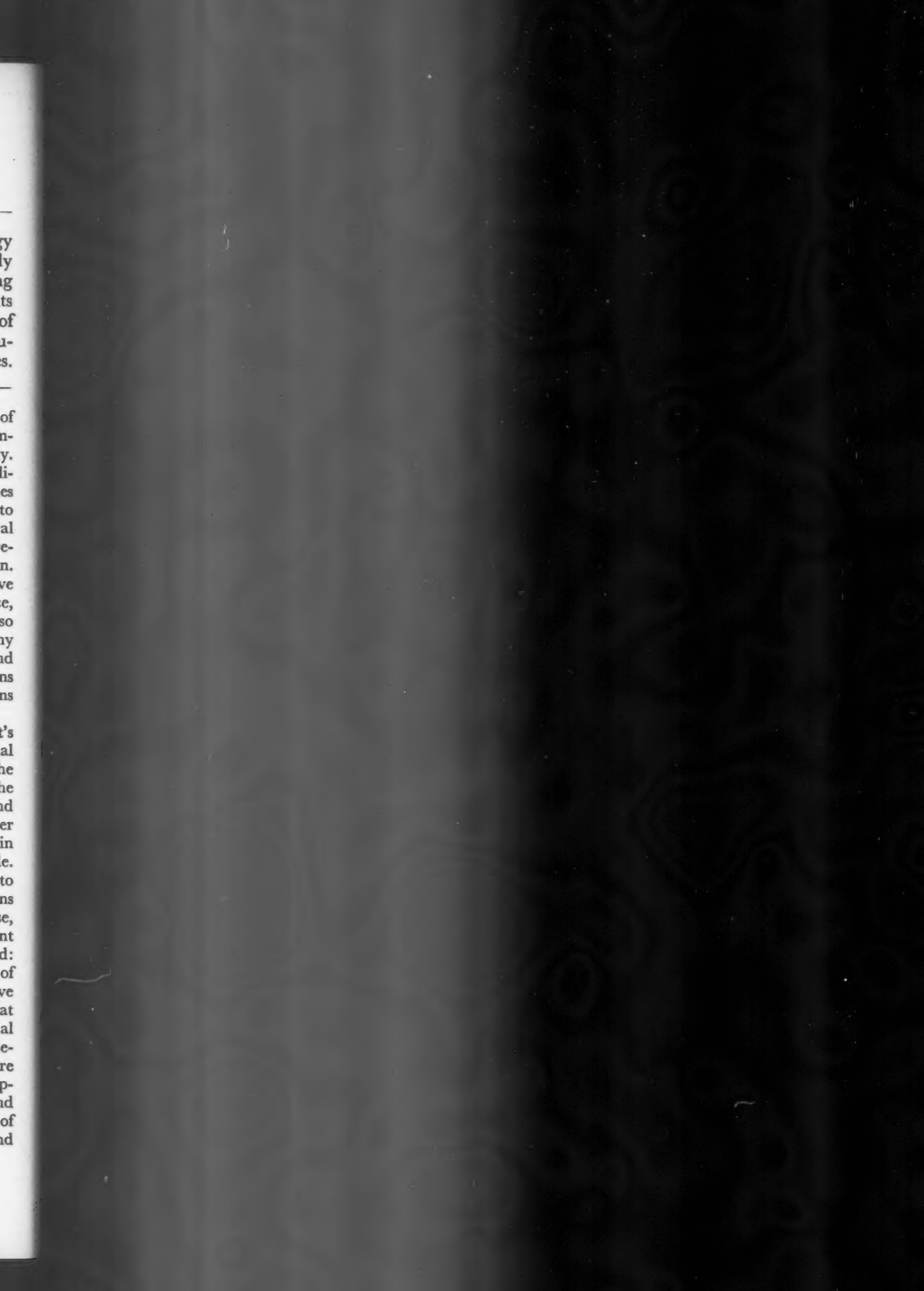

FIGURE 1 – *Two tropical lizards. The naked-necked iguana from tropical America feeds on leaves, and the Lesueur's water-lizard from eastern Australia is carnivorous, feeding largely on insects.*

URE 2 – *The Society owns two pairs of hippopotami. The pair Whipsnade is acclimatized to the open air, and is given artificial rmth only during frosts.*

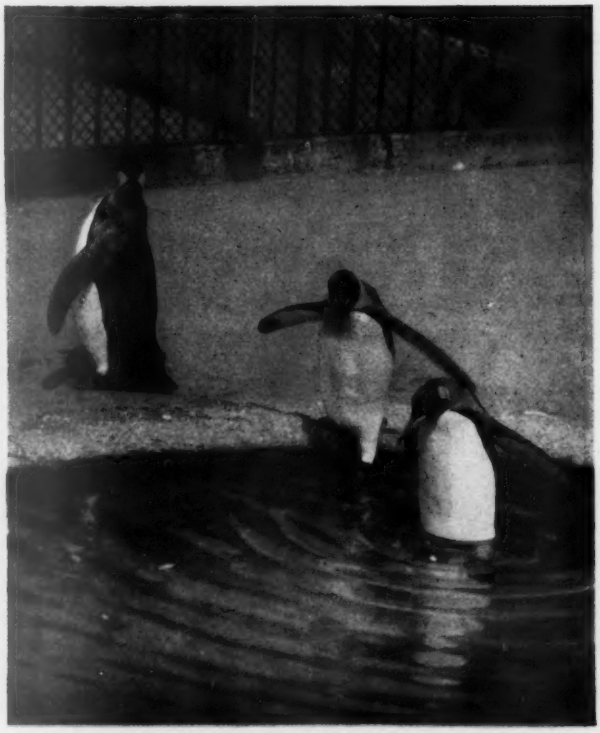

FIGURE 3 – *King penguins, the most beautiful species, are surpassed in size only by the emperor penguins of the extreme south. A king penguin chick was hatched and successfully reared at Regent's Park in* 1952.

FIGURE 4—*The blotched genet of Africa nursing her two kittens. The genet is the only mammal in which cystinuria is known to be a normal condition. Research on the metabolism of the genet now in progress is hoped to reveal new information that will be of value in treating the condition in man, in whom it is pathological.*

FIGURE 5—*Several races of giraffe inhabit Africa. Those shown are reticulated giraffes with a clear-cut net pattern. In other races, the spots are irregular in shape and more widely separated.*

FIGURE 6—*A herd of Indian blackbuck, does on the left and a bu to the right; a young buck, son of the old one, is in the foregrou*

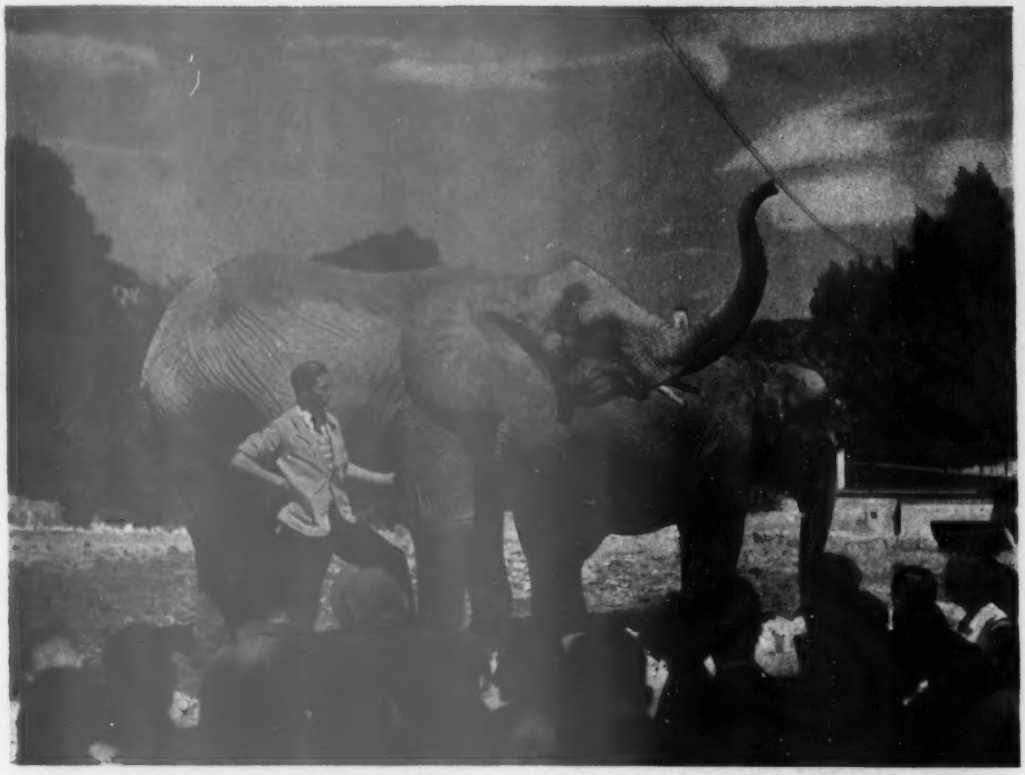

FIGURE 7—*One of the main distinguishing features of the African elephant (in front) is the large size of the ears in comparison with those of the Indian elephant (behind).*

IGURE 8—*Three impala does. The ram of these beautiful African telopes has spreading spiral horns.*

FIGURE 9—*Bears are always popular with Zoo visitors. These young Himalayan bears spend much of their time in the branches of the tree whose trunk is seen behind them.*

FIGURE 10—*A female okapi from the forests of the Belgian Congo. This picture shows the characteristic gait of the okapi, similar to that of its near relatives the giraffes. The feet of one side are moved together, as in a horse trained to pacing.*

FIGURE 11—*Three young spectacled caymans, from South America, basking in their warm tank with only their elevated eyes and nostrils above the surface of the water.*

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presenting a more pleasing appearance to the visitor.

As it is not possible to expand the Zoo in area, the plans for rebuilding make provision for many of the houses to consist of two storeys. The lay-out of the houses will be such that the animal cages will be illuminated, but the halls from which visitors view them will be in semi-obscurity. All the houses will be connected by covered ways, for shelter in wet weather, and advantage will be taken of the natural rise and fall of the ground to avoid the necessity for many flights of steps. The cost of this ambitious rebuilding scheme will be very great, and the plan cannot yet be put in hand. A beginning will be made as soon as possible, but it will obviously be many years before the whole project is completed.

The modern tendency in zoos is to exhibit the animals in enclosures that give some illusion of natural surroundings; the animals are separated from the public by ditches or other barriers but not by the bars of cages. In a zoo like that at Regent's Park, however, space is too limited for this idea to be fully developed, and many of the animals must still be exhibited in cages of one sort or another.

Another modern tendency is to refrain from coddling exotic animals. Traditionally, it was thought necessary to confine animals from warm climates to heated houses, but nowadays it is realized that the most important thing for captive animals is access to plenty of fresh air and sunlight. The provision of artificial warmth is of secondary importance, and heat should be supplied only in moderation, even in severe weather. This development has led to a great improvement in the health of zoo animals, and in particular has much reduced tuberculosis. Old ideas die hard, however, and men who have spent their lifetime looking after captive animals do not find it easy to forget the erroneous lessons learnt in their youth.

The Zoo, as shown by a recent survey, is one of the foremost public attractions in London, but for some obscure reason the public regards it as a place particularly suitable for children. Many people evidently feel that there is something slightly undignified in being interested in animals, and they preserve their self-respect by bringing children with them.

During the last century, when comparative anatomy and systematics took first place in zoology, the Zoo was a favourite centre for zoologists interested in these two fields. Many species of animals were seen alive by zoologists for the first time in the Zoo; they formed the subject of exhaustive researches published in the Society's journals, which were lavishly illustrated with lithographed plates. Although today work in other branches of zoology tends to attract more attention, comparative anatomy still remains one of the foundations on which the science is built; the Society's prosector and others are constantly engaged upon morphological researches that even now are adding much to our knowledge of the structure and interrelationships of animals. A large amount of anatomical material, too, is made available to research workers in universities and other institutions; the results of many of their researches are published in the Society's journals. Material is also supplied for teaching purposes.

In addition to maintaining a permanent scientific staff, the Society has from time to time awarded research fellowships to suitably qualified zoologists, and much interesting work has been accomplished by their holders. During the last two years a scheme of research studentships has been instituted, under which senior undergraduates or recent graduates are enabled to work on various problems in the Zoo during the summer vacation. This scheme has been a great success, and a number of young workers have been able to make a start with research problems; some of them have produced results found worthy of publication in the Society's journals.

Important sections of the Zoo unknown to the public are the sanatorium and the quarantine station. The sanatorium provides hospital accommodation for animals that are sick or have been the victims of accidents; there they are nursed back to health under the supervision of the veterinary officer. He is, incidentally, able to accumulate much useful new knowledge on various aspects of the biology of the animals under his care. The quarantine station accommodates all new arrivals, which are kept under observation for symptoms of disease, and are examined for the presence of internal parasites, before being certified healthy and passed on to the menagerie for exhibition. Several species are subject to strict governmental regulations, and have to undergo a lengthy quarantine in approved premises before they can be moved elsewhere. Many ungulates, after a preliminary period of close quarantine, have to pass through a further quarantine of twelve months in an urban area before they can be sent elsewhere in the country. In consequence, the London Zoo nearly always has a number of such animals on exhibition in Regent's Park until they can be sent

on to the other zoos by which they have been imported.

One of the most important enterprises embarked upon by the Society since its foundation was the building of the aquarium in 1922. In 1853 the Zoological Society of London established what is believed to have been the first public aquarium—it was called an aquatic vivarium in those days—and it is a matter of just pride that the new aquarium, opened in 1923, is universally acknowledged to be the finest aquarium ever constructed in any country. There is a fundamental difference, distinct from size and cost, between the old Fish House and the new installation. The first depended on efforts to establish a balance of life such that animals and plants might be maintained for an indefinite time in unchanged water. The present one uses every appropriate scientific device to keep the water, salt or fresh, in a chemical and physical state closely similar to that of oceans and lakes.

Very large storage reservoirs—containing four or five times the bulk of the water in the exhibition tanks—are needed, and this necessity involves the provision of pumping and circulating plant. It is possible to have a marine aquarium at any distance from the sea if a sufficiently large initial supply of sea-water is obtained, and if the loss by evaporation is replaced by the careful addition of fresh water. When the tanks are so large that it is impossible to remove the greater part of the excreta and other waste, it is necessary to introduce a filtering plant into the circulating circuit, by which impurities may be removed. The success of all these arrangements is plainly to be seen in the magnificent and beautiful collection of water creatures, both marine and fresh-water, that makes such an attractive and instructive exhibition.

An interesting thing about zoos is the way in which some animals become favourites with the public. This is no new phenomenon, for one has only to think of the African elephant Jumbo which was so popular towards the end of the last century. This animal became intractable and the Society decided to sell it, but there was a great public outcry when it was finally disposed of and sent to America, where it shortly afterwards met its end in a railway accident. The name Jumbo became so fixed in the mind of the public that many elephants since that time have been known by it. As a consequence, much confusion has arisen, and zoo elephants in several parts of the world have been claimed as the original Jumbo—hence the many erroneous statements about the great age that this elephant is supposed to have attained.

In recent years the extraordinary mass hysteria that the public exhibited over the polar-bear cub Brumas, which was born in the Zoo in 1951, is quite inexplicable. Polar-bear cubs have been born in zoos often enough, and their advent is a regular occurrence in many. Brumas, however, was the first to be reared successfully in London. How it came about that this particular cub developed such an extraordinary appeal to the public and the press is one of those unfathomable mysteries that come into the realm of psychology rather than of zoology.

Another animal that excited great public interest was the young giant panda exhibited before the last war. This and two adults were the first giant pandas ever to be exhibited in a European zoo, and while it was a young animal it was very attractive in a teddy-bear way. Another giant panda, an adult, was procured after the war, but was a complete failure as far as the public was concerned. Being an adult it spent most of the daytime asleep, and was a very poor subject indeed for exhibition. In addition, the problem of feeding it was very difficult, for bamboo shoots were obtained for it only with great trouble; in the end it died from a vitamin deficiency. Even were it now possible to obtain further specimens, it is very doubtful if the Society would exhibit another.

In contrast with the style of the Regent's Park Zoo, with houses and cages, Whipsnade Park, thirty miles from London, goes to the other extreme. Whipsnade was originally designed, in part, as a sort of holiday camp for the animals from Regent's Park, but it has now developed into a zoological park in its own right. Most of the animals there are exhibited at comparative liberty in very large paddocks, where they roam about much as they do in the wild. It is twenty-one years since the development of Whipsnade began, and during that time great advances have been made. Many improvements have been completed since the end of the war. The very beautiful rural setting forms a splendid background for the birds and animals exhibited.

Whipsnade and Regent's Park are complementary to each other, and between them they are able to show the finest collection of wild animals in the world. They will continue to make important contributions to the science of zoology, and at the same time they will increase in popularity with the general public as places of relaxation, recreation, and—we may hope—unconscious education.

Detergent action

N. K. ADAM and D. G. STEVENSON

The use of soap solutions for removing dirt from textiles and other materials has been general for very many centuries [1]. During the last twenty years, much progress has been made in understanding the various mechanisms by which aqueous solutions of soap, and of other detergents, dislodge dirt from a solid surface and retain it in suspension, so that it may be rinsed away easily by water. Some modern work on the subject is described in this article.

Most, though not all, water-soluble detergents belong to the class of substances known as paraffin-chain salts. These substances, which include soaps proper, contain a long hydrocarbon chain—sometimes more than one—with a water-soluble, electrolytically dissociated group, usually at or very near the end of the chain. They all show strong surface activity: they are strongly adsorbed at interfaces, and even in very dilute solution decrease the surface tension of water, and the interfacial tension against oils, to low values. Chevreul and others, early in the nineteenth century, recognized that soaps have a powerful emulsifying action on greasy dirt, and late in that century [2] the fundamental connection between emulsifying power and the ability to lower interfacial tension was recognized. Hillyer [3] showed that soap assists penetration of water into the interstices of cloth, a process which is now called wetting-out. Both wetting-out and emulsifying power are desirable in any detergent. The first is a preliminary, since detergent action cannot begin until the detergent solution is in good contact with all parts of the surface; the second is a desirable sequel, since unless the surface of the dirt is rendered sufficiently hydrophilic it may not remain in suspension, but is liable after removal to be deposited on the solid again.

Detergent action proper is usually displacement of the dirt, generally of a greasy nature, from the solid surface by the detergent solution. This was studied by Adam, using photomicrography, and was first described in 1937 [4]; but Hailwood had previously (1932) worked out much of the theory. The displacement may be called a rolling-up process, since the grease, initially spread as a more or less continuous film on the solid surface, is collected and rolled up into globules adhering only locally and very loosely to the solid. The detergent, often in very small concentration in the water, brings about a drastic change in the angle of contact formed by the water-grease surface with the solid surface, shown diagrammatically in figure 1. In water alone (figure 1*a*), the contact angle θ_{ow}, measured in the grease, is nearly zero, the complementary angle θ_{wo} in the water being 180°. In a dilute detergent solution (figure 1*b*), θ_{ow} changes to 180°, and θ_{wo} to 0°. The effect of a small concentration of detergent is to cause the solid to be wetted by water instead of by grease. Once rolled up, the globules of grease either detach themselves spontaneously, or touch the solid over only a very small area and are thus very easily dislodged by slight agitation.

Figure 2 shows wool fibres greased with lanoline stained red (appearing black in the photographs), in various concentrations of cetyl sodium sulphate, $C_{16}H_{33}OSO_3^-$, Na^+. In extremely dilute (0·001 per cent.) solution, displacement is inappreciable (figure 2*a*); the grease still covers the fibre as a nearly continuous film. In figure 2*b* (0·005 per cent.), the grease is collected into separate globules, but displacement is incomplete, the contact angle in the oil being between 45° and 90°. In figure 2*c* (0·02 per cent.), the grease is completely rolled up and nearly detached, and the contact angle in the oil is 180°. Figure 2*d* shows the fibres in 0·02 per cent. solution after a slight shake; all the globules of grease have been removed. Figure 3 shows clear photographs of stages in rolling-up, taken by R. C. Palmer [5].

It is easy to see that adsorption of detergent at the solid-water and oil-water surfaces will tend to roll up the grease. From figure 1 it is clear that the solid-oil (γ_{so}), solid-water (γ_{sw}), and water-oil (γ_{wo}) tensions are related by

$$\gamma_{so} = \gamma_{sw} + \gamma_{wo} \cos \theta_{wo}$$

$$\cos \theta_{wo} = \frac{\gamma_{so} - \gamma_{sw}}{\gamma_{wo}} \quad \ldots\ldots\ldots\ldots (1)$$

Both the tensions γ_{sw} and γ_{wo} will be decreased by adsorption of the detergent, in the form of

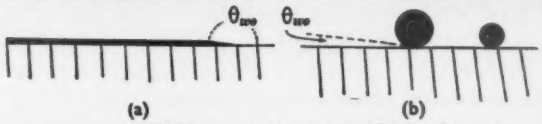

FIGURE 1 – *Rolling-up* (a) *in water,* (b) *in detergent.*

films probably one molecule thick, at the water-solid and water-oil surfaces. By equation (1), a decrease in either or both of these surface tensions will increase cos θ_{wo} and decrease θ_{wo}, and therefore help to roll up the grease. The adsorption of detergent at the solid surface may be regarded as a displacement of the grease by the film of detergent molecules, which adhere more strongly to the surface than does the grease. In their action on the solid surface, the detergent molecules undermine the grease, performing much the same function as road-sweepers—who collect the dirt, at first spread more or less uniformly over the road, into heaps which may easily be transferred to a cart. The detergent molecules have another function, however; by their adsorption on, and lowering of the tension of, the water-grease surface, they help to disperse the globules of grease (which are easily shaken off the solid surface after rolling-up) as a fairly stable emulsion in the water.

Most detergent solutions foam readily, and the housewife often judges the quality of her washing water by the amount of lather it forms. Lather is not, however, a necessary condition for detergent action; Sisley [6] states that, when the foam on a soap solution is reduced or destroyed by anti-foaming agents such as tributyl phosphate, detergent power may be little affected. Further, some liquids which foam very well, such as saponin solutions, have little detergent power. Foaming and detergent action are independent consequences of the surface activity of detergents: foaming results from adsorption at the water-air surface, and detergent action from adsorption at the water-solid and water-oil surfaces, as we have seen above. There is some reason for the frequent association of foaming and detergent power. The strong surface activity of most detergents is due to the large amount of hydrocarbon in their constitution. This hydrocarbon always tends to come out of solution in water, because the water molecules attract each other so much more strongly than they attract hydrocarbon, or than hydrocarbon attracts other hydrocarbon, that the water molecules try to crowd together and squeeze out the hydrocarbon parts of the detergent molecules. Strong foaming of a solution shows the presence of a highly surface-active solute, which will probably be adsorbed on any surface in contact with the water. Further, with soap solutions, the appearance of a stable lather indicates that there is soluble soap in solution available for detergent action; if no lather is formed, it is generally because all the soap is precipitated by calcium or magnesium ions in the water. Nevertheless, it is unlikely that the adsorption of detergent at the air-water surface, which produces foam, has much direct influence on the detachment of dirt from a solid surface.

Foam does, however, have a definite action on oil displaced from a solid surface. D. G. Stevenson studied the effect of foams of several detergents on smears of oil on glass surfaces, and showed that oil concentrates in the junctions between the lamellae of films in the foam. Figure 6*a* is a smear of Oildag (a suspension of colloidal graphite in mineral oil) on glass; 6*b* the same after 15 seconds in contact with a foam made from a solution of a secondary alkyl sulphate (Teepol); 6*c* after 45 seconds; 6*d* after 3 minutes. These photographs were taken through glass, the smear and foam being behind the glass. Figure 4 shows a little Oildag dispersed in a foam away from any solid surface. Figure 5 shows a very small amount of Oildag in a coarse foam in a beaker; the whole of the oil is collected into a beautiful four-rayed star. The most probable reason why the oil collects in the junctions between the lamellae is that the curvature is greatest at these junctions, and consequently the pressure in the liquid least, since the curvature is strongly concave towards the air. The foam breaks up the oil into very fine lines, which in turn break up into small droplets when the foam breaks, thus assisting dispersal of the oil as an emulsion.

Unless the solution produces the change in contact-angle which results in rolling-up the oil, the oil smear is not removed from the surface by foam. Figure 9*a* shows a broad ring of oil painted inside a glass tube; the light patch with a dark line is on the outside of the tube to mark the position of the smear. Figure 9*b* shows the same after 10 cm of secondary alkyl sulphate foam, moving at about 3 cm per minute, has passed over the smear; most of the oil has been removed and carried some distance along the tube. In 9*c*, after 30 cm of the same foam has passed, all the oil has been removed from the region shown in the photograph, only the black line on the outside of the tube, marking the position of the smear, remaining. Figure 9*d* shows the action of a moving solution with the same concentration of secondary

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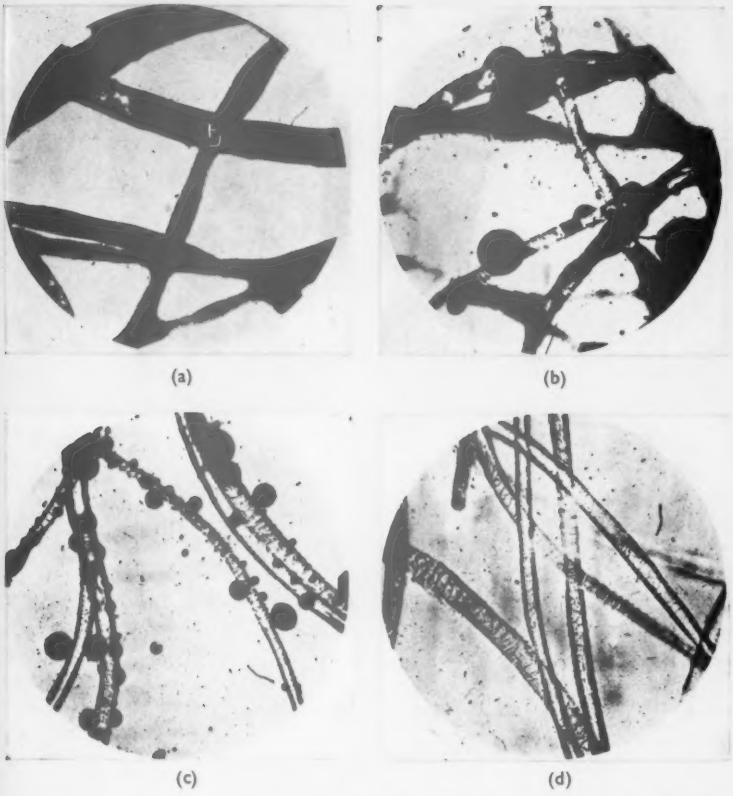


FIGURE 2 – *Displacement of lanoline (black) from wool by cetyl sodium sulphate* (× c 80). (a) 0·001 *per cent.*, (b) 0·005 *per cent.*, (c) 0·02 *per cent.*, (d) 0·02 *per cent. (shaken).*

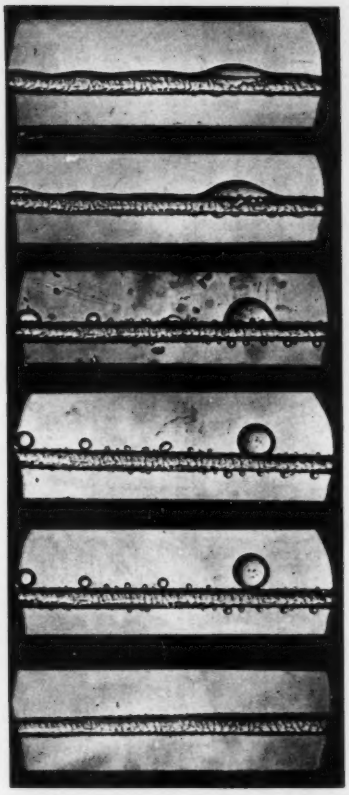


FIGURE 3 – *Stages in rolling-up.*

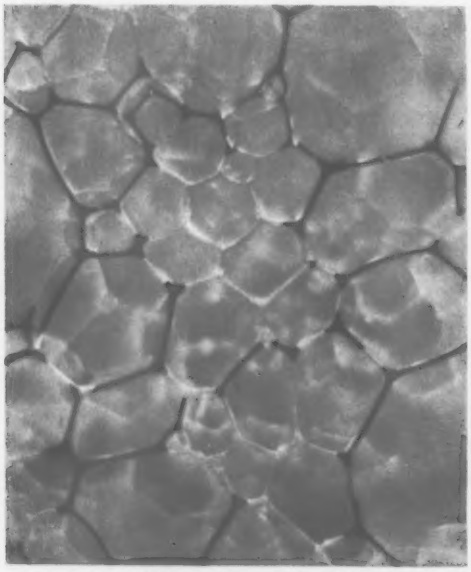


FIGURE 4 – *Oildag dispersed in foam.* (× c 16)

FIGURE 5 – *Trace of Oildag in coarse foam.*

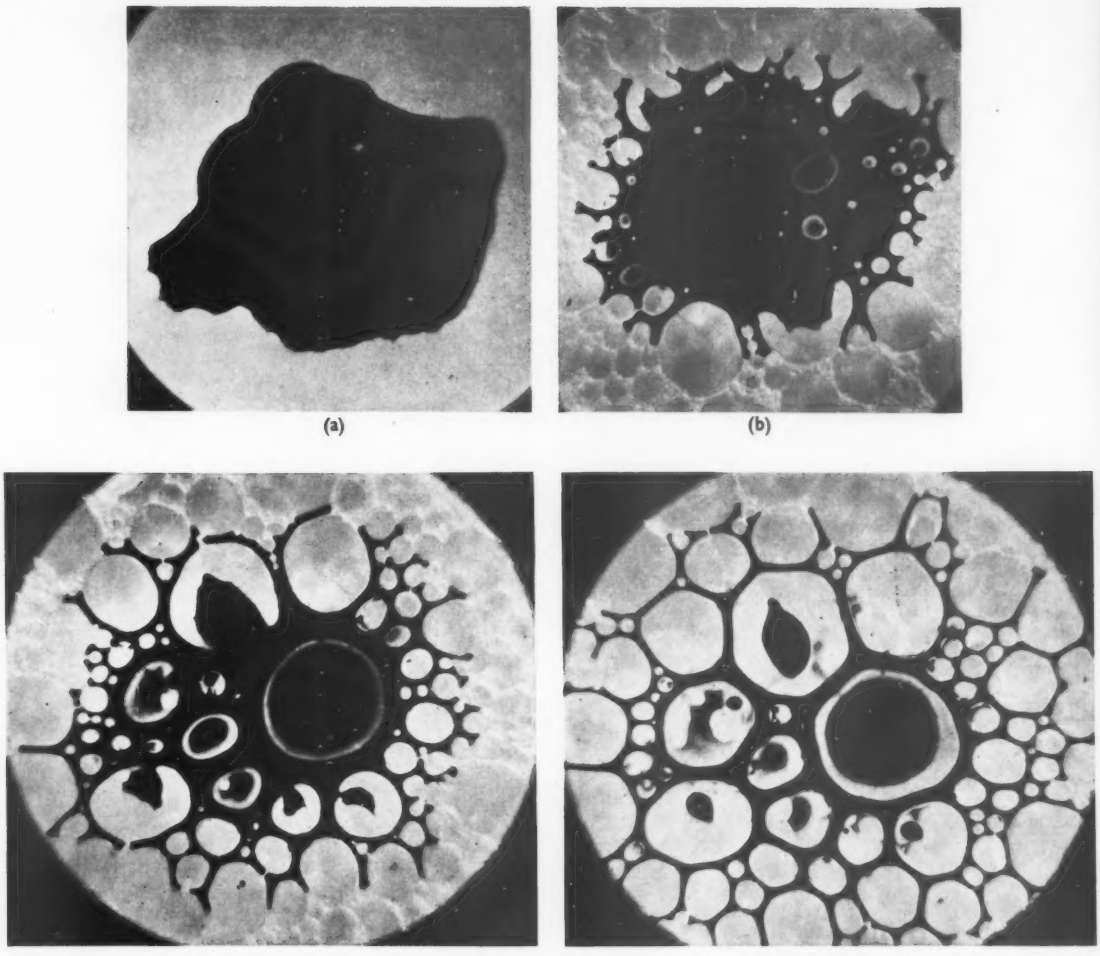


FIGURE 6 – *Action of* 0·2 *per cent. secondary alkyl sulphate foam on Oildag patch* (× c 8)*:* (a) *before contact with foam,* (b) 15 *sec,* (c) 45 *sec,* (d) 3 *min.*

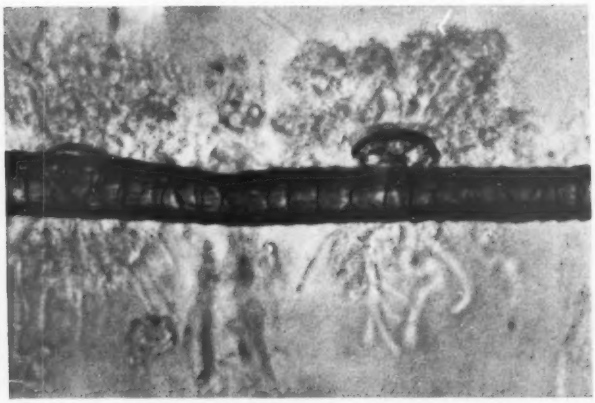


FIGURE 7 – *Oleic acid on fibre, in* 0·2 *per cent. sodium oleate,* 3 *min.* (× c 300)

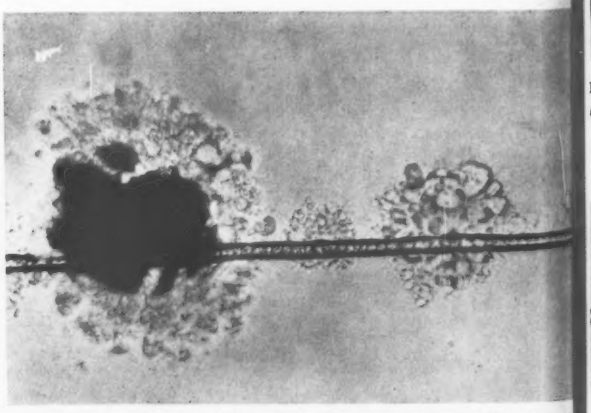
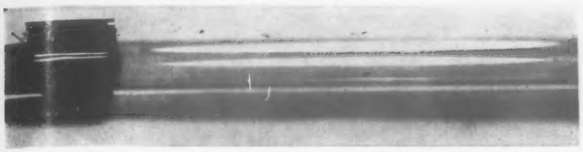


FIGURE 8 – *Lauric acid on fibre, in* 0·5 *per cent. sodium laurate,* 5 *min.* (× c 100)



(a)

(b)

(c)

(d)

FIGURE 9 – (a) *Oildag smear inside glass tube.* (b) 0·2 *per cent.* sec-*alkyl sulphate foam, moving* 3 *cm per minute, after* 10 *cm had passed.* (c) *Same after* 30 *cm foam had passed.* (d) *Similar smear after solution had passed* 3 *min, without foam.*

FIGURE 10 – *Similar smear after* 30 *cm cetyl trimethyl-ammonium bromide foam had passed.*

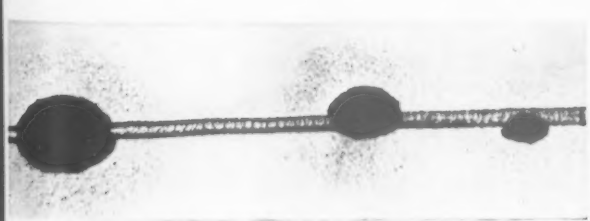


FIGURE 11 – *Lauric acid on fibre, in* 1 *per cent.* sec-*alkyl sulphate,* 15 *min.* (× C 100)

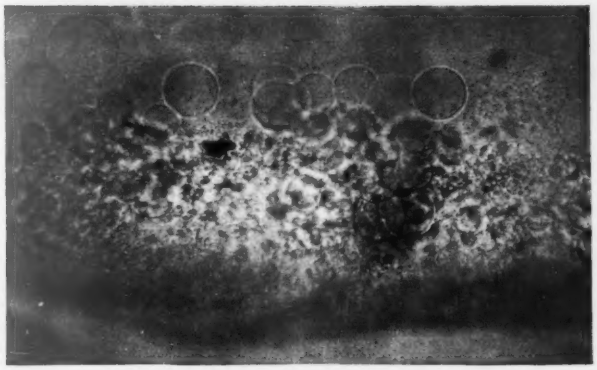


FIGURE 12 – sec-*dodecyl alcohol in* 1 *per cent. sodium laurate,* 10 *min.* (× C 100)

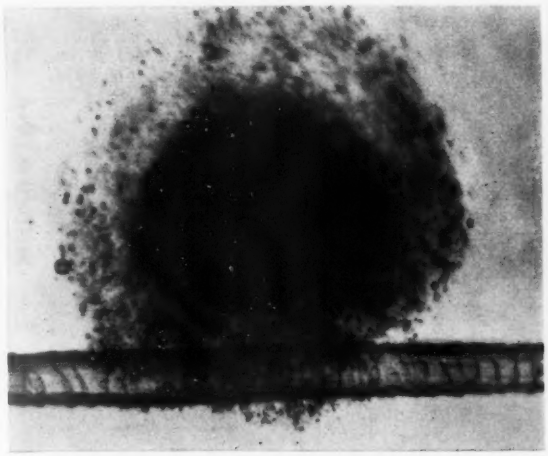
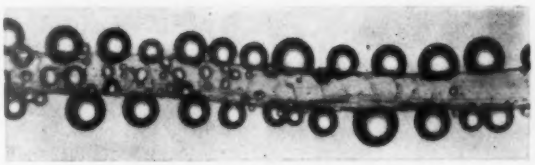


FIGURE 13 – *Dirt on fibre, in* 0·2 *per cent. sodium oleate,* 2 *min.* (× C 300)

(a)

(b)



(c)

FIGURE 14 – *Growth of aqueous droplets on saline wool under Nujol.* (a) 1 *hour, under drop,* (b) 8 *hours, under drop,* (c) *under continuous film.*

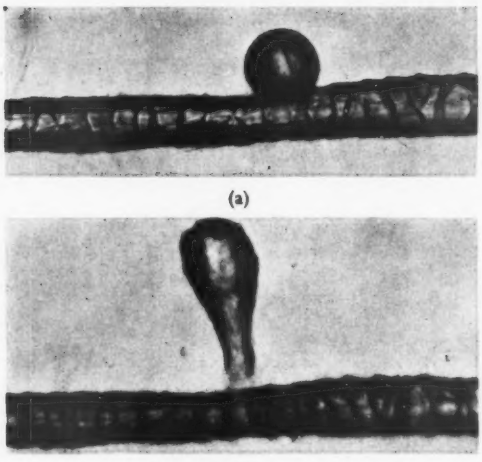


FIGURE 15 – 3 : 1 *mixture of Nujol : oleic acid, in* 0·2 *per cent. non-ionic detergent* (× c 300). (a) 30 *sec*, (b) $3\frac{1}{2}$ *min.*

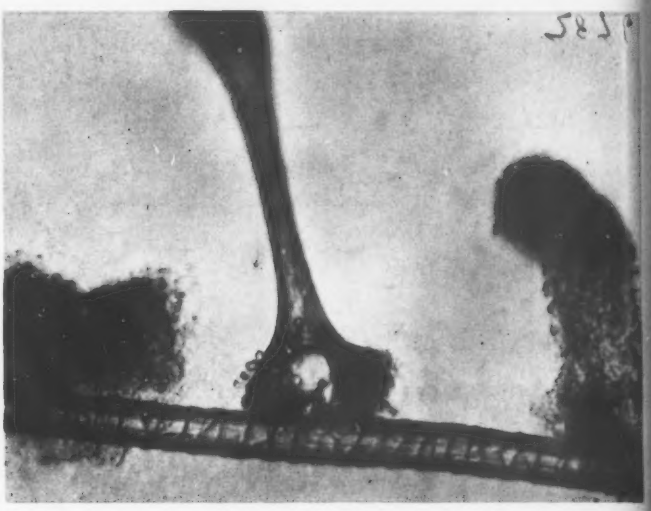


FIGURE 16 – 3 : 1 *mixture of Nujol : oleic acid, in* 0·05 *per cent. non-ionic detergent,* 30 *min.* (× c 300)

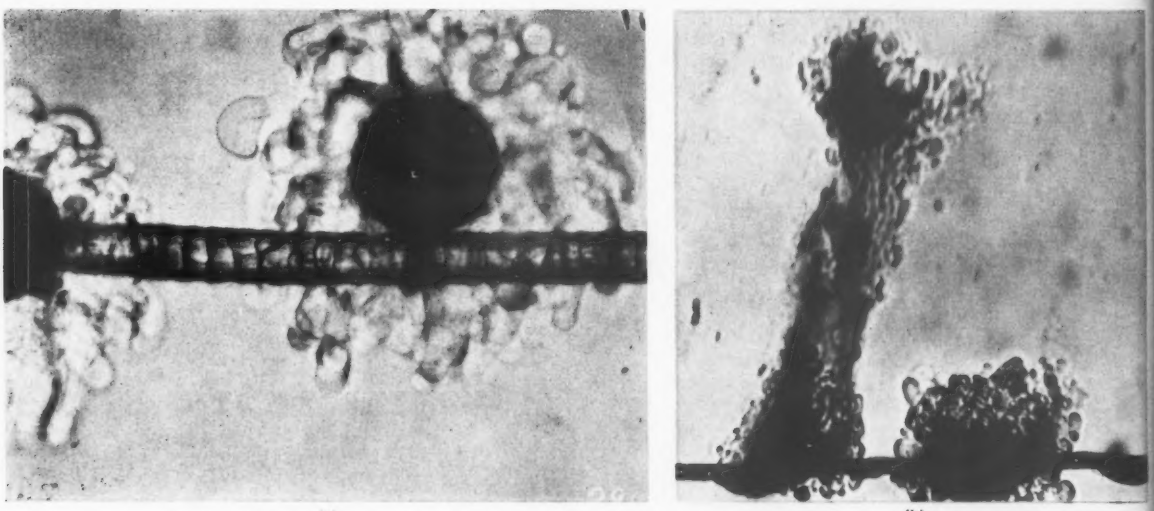


FIGURE 17 – 3 : 1 *mixture of Oildag : oleic acid, in* 1·5 *per cent. non-ionic detergent.* (a) 11 *min.* (× c 300), (b) 30 *min.* (× c 80)

Our thanks are due to the 'Journal of the Society of Chemical Industry,' the 'Journal of the Textile Institute,' and the 'Journal of the Society of Dyers and Colourists,' for permission to reproduce photographs; and to the British Launderers' Research Association for permission to publish this article.

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alkyl sulphate, but without foam, on a similar smear of oil; the oil is rolled up into globules, but is not carried along the glass under the very slight agitation of the moving liquid. One advantage of the foam may be that it has slight rigidity, sweeping the rolled-up globules of oil mechanically off the surface and thus helping to detach them; the oil is then sucked into the interlamellar junctions.

This secondary alkyl sulphate solution has considerable rolling-up power. By contrast, a foam of the cationic paraffin-chain salt cetyl trimethylammonium bromide is much less effective, as its rolling-up power is very small. In fairly dilute solution, cationic paraffin-chain salts render glass hydrophobic; in the concentration employed (0·2 per cent.), the contact angle in the solution was 150°, instead of the 0° in a good detergent. Figure 10 was taken after about 30 cm of foam had passed over the smear, at the same rate as the alkyl sulphate shown in figure 9*c*. Instead of being completely removed, the oil has merely been dragged a little way along the inside of the tube.

Thus foam may assist detergent action (*a*) by increasing the mechanical removal of dirt, as it moves over the surface of the solid, and (*b*) by assisting in the break-up of the oil into tiny globules which are easily emulsified.

The three mechanisms of detergent action described above, namely rolling-up, dispersion of detached oil in foam, and emulsification, do not involve any solvent action of the detergent solution on the dirt. However, detergent solutions frequently dissolve a certain amount of substances insoluble in water but soluble in hydrocarbon solvents. This is called assisted solubility or solubilization [8]. It is made possible by the peculiar internal constitution of solutions of paraffin-chain salts, above a definite concentration known as the critical concentration for micelle formation (c.m.c.). Above the c.m.c., ionic micelles are formed, in the interior of which the long hydrocarbon chains are packed together, with the water-soluble end-groups directed outwards to the water and covering, as far as their number permits, the hydrocarbon interior of the micelle.

There is argument as to the structure of ionic micelles; some investigators consider that they are spherical or nearly so, others believe them to be cylindrical, and still others regard them as lamellar. In spherical or cylindrical micelles the hydrocarbon chains are packed in the interior, probably in an irregular manner, the surface containing all the water-soluble groups. The lamellar theory pictures a micelle as two layers of very large extent, each one molecule thick, with the molecules in each layer oriented in opposite directions, so that the middle of the micelle is entirely hydrocarbon; the two opposite faces of the lamella contain all the water-attracting groups. The spherical or cylindrical shapes appear more probable than the lamellar, but, whatever the shape, there seem to be two ways in which micelles can dissolve substances insoluble in water. Non-polar substances dissolve in the hydrocarbon interior; molecules containing a good deal of hydrocarbon, and a polar, water-attracting group near the end, probably orient themselves with the polar groups at the surface, while the hydrocarbon part is buried in the hydrocarbon interior of the micelles.

As the micelles are much smaller than the wavelength of light, perfect solubilization results in a clear solution. All that can be seen when an oil drop is dissolving in a detergent solution is a faint halo near the drop, where the refractive index is different from that in more distant regions of the solution, where less oil has been solubilized. Although attention has often been drawn to the possibility that solubilization plays a part in detergent action [9], there is as yet little evidence that it is of practical importance, except perhaps in detergent solutions more concentrated than those usually employed in washing.

More dilute detergent solutions, acting on greasy dirt containing a proportion of substances with polar groups, often cause the dirt to swell and come off the fibre in very remarkable complex growths. These growths have been studied recently by Stevenson [10]. A common form is the myelinic complex, shown in figures 7 and 8. In this variety, soon after the solution comes into contact with the grease tentacles develop at the surface, growing outwards and forming a tangled gelatinous mass several times the volume of the grease from which they started. Myelinic forms, so called because they appear when crude lecithin from the myelinic sheath of nerves is immersed in water, have long been known; they are described in Lehmann's *Molekularphysik* (1888) [11] and were not new even then. Figure 11 shows a finer myelinic growth, formed in a secondary alkyl sulphate solution. Occasionally, the complex takes the form of an aggregate of small spheres, as with secondary dodecyl alcohol in a sodium laurate solution (figure 12).

The gelatinous character of these complexes makes it difficult to rinse them away from the fibre; moreover, they are often decomposed on

FIGUR
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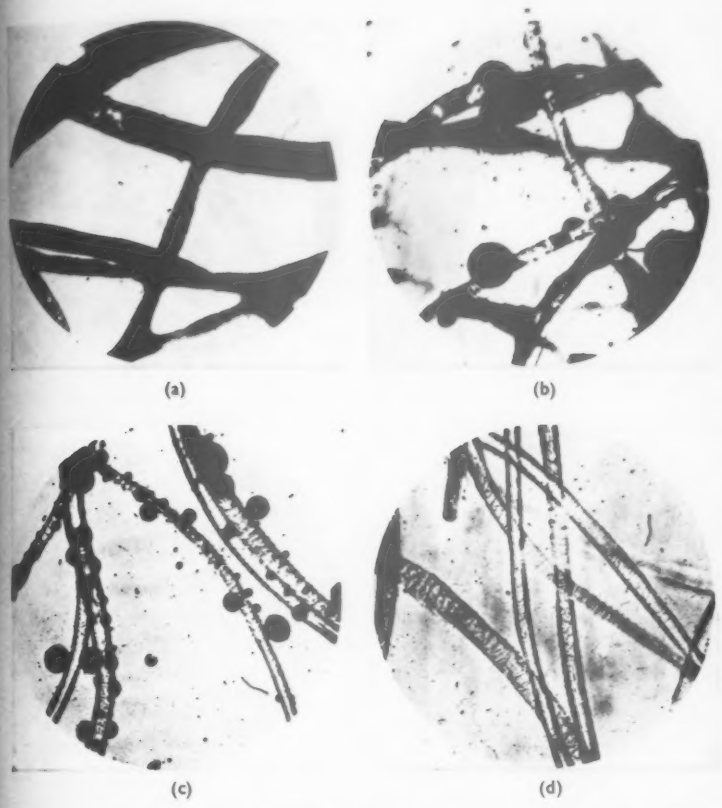

FIGURE 2 – *Displacement of lanoline (black) from wool by cetyl sodium sulphate* (× c 80). (a) 0·001 *per cent.*, (b) 0·005 *per cent.*, (c) 0·02 *per cent.*, (d) 0·02 *per cent. (shaken).*

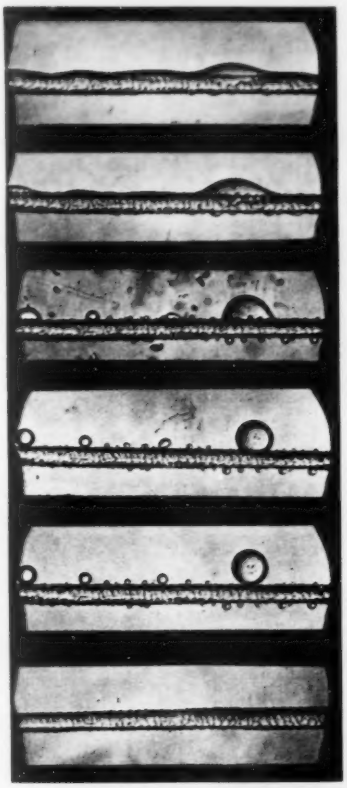

FIGURE 3 – *Stages in rolling-up.*

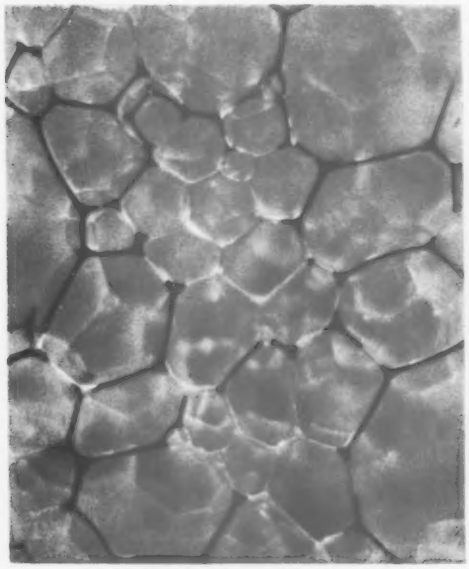

FIGURE 4 – *Oildag dispersed in foam.* (× c 16)

FIGURE 5 – *Trace of Oildag in coarse foam.*

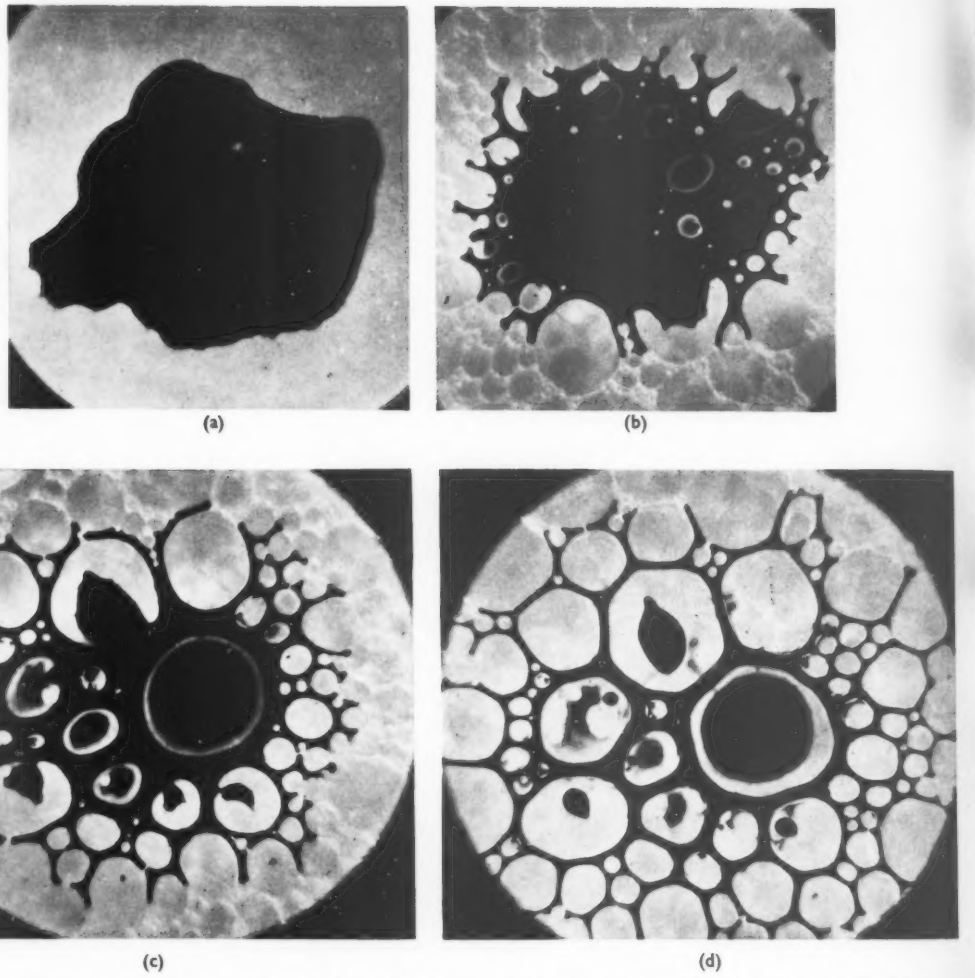

FIGURE 6 – *Action of* 0·2 *per cent. secondary alkyl sulphate foam on Oildag patch* (× c 8)*:* (a) *before contact with foam,* (b) 15 *sec,* (c) 45 *sec,* (d) 3 *min.*

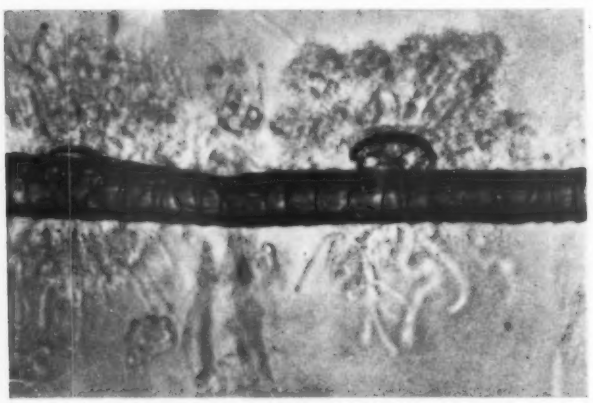

FIGURE 7 – *Oleic acid on fibre, in* 0·2 *per cent. sodium oleate,* 3 *min.* (× c 300)

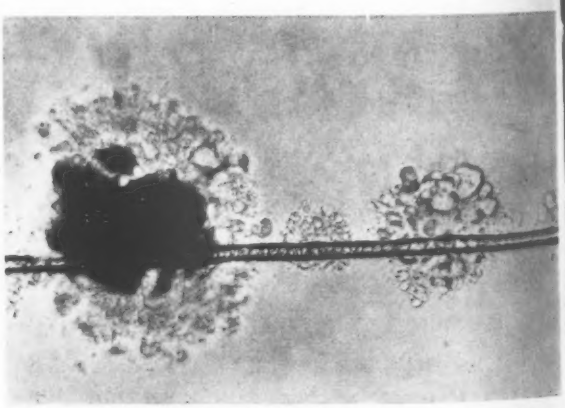

FIGURE 8 – *Lauric acid on fibre, in* 0·5 *per cent. sodium laurate,* 5 *min.* (× c 100)

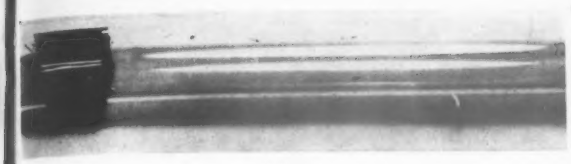

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FIGURE 9 – (a) *Oildag smear inside glass tube.* (b) 0·2 *per cent.* sec-*alkyl sulphate foam, moving* 3 *cm per minute, after* 10 *cm had passed.* (c) *Same after* 30 *cm foam had passed.* (d) *Similar smear after solution had passed* 3 *min, without foam.*

FIGURE 10 – *Similar smear after* 30 *cm cetyl trimethyl-ammonium bromide foam had passed.*

FIGURE 11 – *Lauric acid on fibre, in* 1 *per cent.* sec-*alkyl sulphate,* 15 *min.* (× c 100)

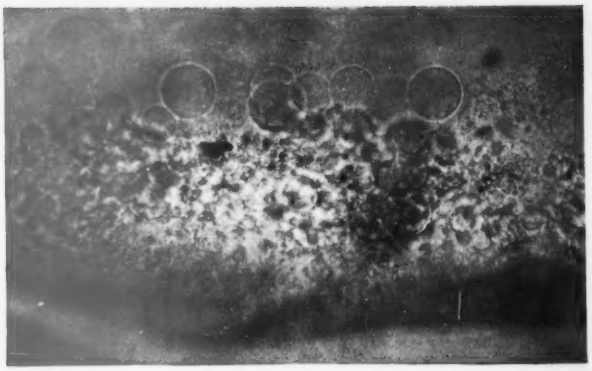


FIGURE 12 – sec-*dodecyl alcohol in* 1 *per cent. sodium laurate,* 10 *min.* (× c 100)

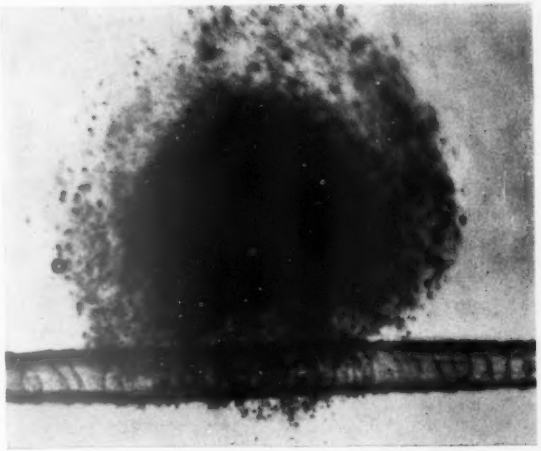


FIGURE 13 – *Dirt on fibre, in* 0·2 *per cent. sodium oleate,* 2 *min.* (× c 300)

(a)

(b)

(c)

FIGURE 14 – *Growth of aqueous droplets on saline wool under Nujol.* (a) 1 *hour, under drop,* (b) 8 *hours, under drop,* (c) *under continuous film.*

(a)

(b)

FIGURE 15 – 3 : 1 *mixture of Nujol : oleic acid, in* 0·2 *per cent. non-ionic detergent* (× c 300). (a) 30 *sec*, (b) 3½ *min.*

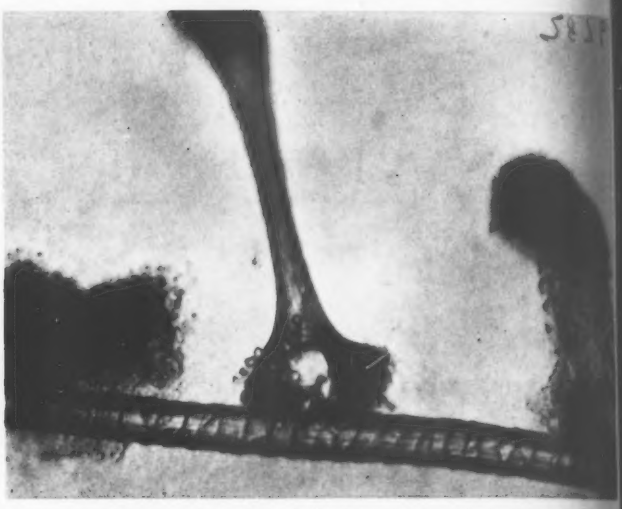
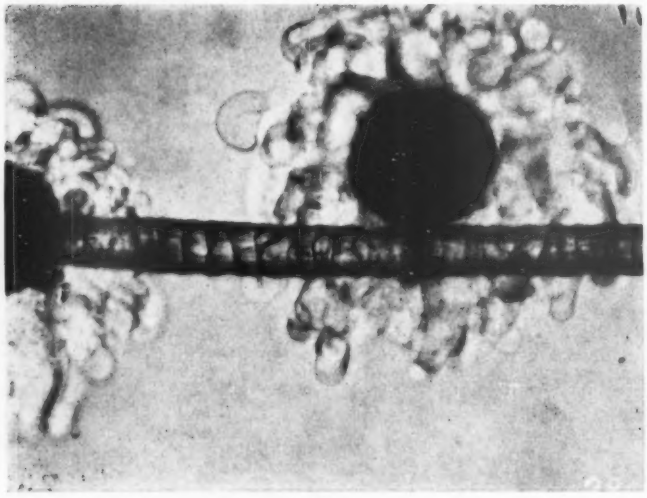


FIGURE 16 – 3 : 1 *mixture of Nujol : oleic acid, in* 0·05 *per cent. non-ionic detergent,* 30 *min.* (× c 300)



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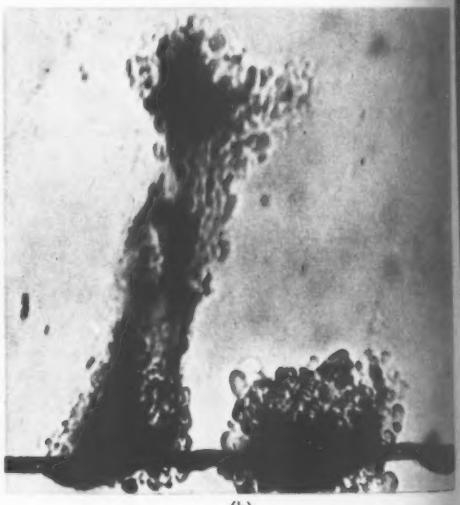

(b)

FIGURE 17 – 3 : 1 *mixture of Oildag : oleic acid, in* 1·5 *per cent. non-ionic detergent.* (a) 11 *min.* (× c 300), (b) 30 *min.* (× c 80)

Our thanks are due to the 'Journal of the Society of Chemical Industry,' the 'Journal of the Textile Institute,' and the 'Journal of the Society of Dyers and Colourists,' for permission to reproduce photographs; and to the British Launderers' Research Association for permission to publish this article.

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alkyl sulphate, but without foam, on a similar smear of oil; the oil is rolled up into globules, but is not carried along the glass under the very slight agitation of the moving liquid. One advantage of the foam may be that it has slight rigidity, sweeping the rolled-up globules of oil mechanically off the surface and thus helping to detach them; the oil is then sucked into the interlamellar junctions.

This secondary alkyl sulphate solution has considerable rolling-up power. By contrast, a foam of the cationic paraffin-chain salt cetyl trimethylammonium bromide is much less effective, as its rolling-up power is very small. In fairly dilute solution, cationic paraffin-chain salts render glass hydrophobic; in the concentration employed (0·2 per cent.), the contact angle in the solution was 150°, instead of the 0° in a good detergent. Figure 10 was taken after about 30 cm of foam had passed over the smear, at the same rate as the alkyl sulphate shown in figure 9*c*. Instead of being completely removed, the oil has merely been dragged a little way along the inside of the tube.

Thus foam may assist detergent action (*a*) by increasing the mechanical removal of dirt, as it moves over the surface of the solid, and (*b*) by assisting in the break-up of the oil into tiny globules which are easily emulsified.

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The gelatinous character of these complexes makes it difficult to rinse them away from the fibre; moreover, they are often decomposed on

dilution with water, the original dirt being precipitated. This may account for the yellow centres sometimes found after laundering pillow-slips; grease has been forced into the cloth, the detergent solution forms complexes with it, and normal rinsing does not remove these complexes from the very narrow interstices between the threads.

In some circumstances, oil on a fibre may spontaneously emulsify in a detergent solution. Soap solutions are particularly effective in emulsifying oil containing polar material. Figure 13 shows a globule of oil containing some fatty acid, extracted from soiled pillow-slips, being removed from a salt-free wool fibre by sodium oleate solution. The oil is rolled up, and is being emulsified wherever the surface is in contact with the detergent.

Another phenomenon, first observed by J. Powney in 1944, and recently explained by Stevenson [12], is the growth of droplets of water on fibres, underneath oil adhering to the fibre. These are formed when the fibres contain salt, or other material with low molecular weight (as they usually do unless special precautions have been taken to wash such substances out), and the oil-covered fibre is immersed in an aqueous solution whose osmotic pressure is not too high. Figures 14*a* and 14*b* show two stages in the growth of these droplets under oil drops; 14*c* shows droplets under a continuous thick film of oil. The droplets grow by osmosis, water passing from the dilute solution outside the fibre to the concentrated solution between the fibre and the oil. They shrink when the oiled fibre is immersed in strong salt solution. The droplets may sometimes assist detergent action by breaking up the oil, but they are probably not of major importance for washing.

Rise of temperature normally assists detergent action, in several ways. For easy removal, the dirt should be above its melting-point, or the surface tension effects involved in rolling-up will not operate properly. Further, unless the temperature is above a certain fairly well defined level, sometimes known as the Krafft point, soaps and other paraffin-chain salts have very low solubility. Below this temperature, the solubility may be less than 0·1 per cent.; above, it is very large, possibly 50 per cent. This sudden change in solubility is due to the formation of very soluble ionic micelles, which occurs when the solubility of the sparingly soluble single ions just reaches the critical concentration (c.m.c.) at which ionic micelles begin to form in quantity. Above the Krafft point, solubilization of oil is possible on a considerable scale, if the detergent solution is sufficiently concentrated. The complex growths often formed in dilute detergent solutions tend to dissolve if the detergent solution is sufficiently concentrated and if the temperature is fairly high.

Rise of temperature introduces one factor adverse to detergent action. Adsorption is decreased as the temperature rises, and therefore the interfacial tension between oil and water is higher, and the dispersing power of the detergent on the dirt removed may be less, than at lower temperatures.

The above account applies mainly to ionized detergents of the paraffin-chain salt type. Less is known about the action of the recently introduced non-ionic detergents, or indeed about the constitution of their solutions. Important among non-ionic detergents are compounds with an alkylated phenol, or some other group containing much hydrocarbon, at the end of a polyoxyethylene oxide chain, such as

n being of the order of 10. Photomicrographic studies [10] show that this detergent has some rolling-up power, probably less than the paraffin-chain salts, but a considerable power of lowering interfacial tension and emulsifying oils. Figure 15*a* shows the oil rolled up; in 15*b*, rather later, it is beginning to come away as a pear-shaped drop from a salt-free fibre. Figure 16 shows considerable emulsification on a wool fibre containing its natural salt. Figure 17*a* shows a removal beginning as complex formation; some minutes later the whole oil drop began to emulsify (figure 17*b*).

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Morphological changes in chondriosomes

R. BUVAT

Cells contain a variety of microscopic structures whose precise identification is difficult. Among the most distinct are the rods or granules known as chondriosomes, the function of which is uncertain; it is clear, however, that they are active agents, and not merely products of metabolism. A puzzling feature is their ability to vary greatly in number, size, and proportions; these morphological changes may all be determined by the action of water.

In the course of variation in the physiological activity of the protoplasm the morphology of the chondriosomes sometimes changes in an interesting way. The chondriosomes are known to be fragile; they are destroyed by the usual fixatives such as alcohol or acetic acid, and in general by all fat-solvents. They are affected by many substances normally foreign to the cytoplasm, and are particularly sensitive to the action of water. This last fact is probably related to the presence of phospholipids, in which they are very rich. In effect, these bodies, although fat-soluble, have a certain affinity for water; the so-called myelin processes, which follow the uptake of water, are well known (see p. 31). These properties explain how the vacuoles, which are hydrophilic regions in the cytoplasm, can sometimes contain phospholipid substances (Mirande [21–3], Miraton [24], Reilhes [25, 26], Buvat [5]).

On observing the effects of different chemical or physical agents on the chondriosomes, it is found that the changes produced are almost always of the same kind, and, further, that they are identical with the changes produced by pure water. We shall try to show that the morphological changes in the chondriosomes are probably due in all cases to the action of water.

GENERAL

In the vacuoles of cells, water forms pseudo-solutions and true solutions with colloids and crystalloids; in the cytoplasm and the nucleus it exists principally in molecular form, bound to the macromolecules of the living substance by forces similar to those associated with the imbibition by colloids. The bonds between the water and the macromolecules of the protoplasm are unstable, and change with changing conditions of the medium and with the physiological activity of the cells. The protoplasm can, in fact, take up water, from the vacuoles or from the medium, or can give it up. Molecules of free water can thus exist and move about in the protoplasm.

The work of Frey-Wissling [13] has shown that the protein macromolecules of living matter are also unstably linked with one another. Thus the thixotropy of the cytoplasm—a partial, reversible transformation from plasmagel to plasmasol—results from changes in the forces which bind the macromolecules together.

It seems likely that the bonds between the macromolecules, and between the macromolecules and the water, are affected by the same factors. Thus coagulation of the cytoplasm, which irreversibly increases the forces linking the macromolecules, at the same time suppresses the bonds between the macromolecules and the water. It is known, too, that factors which stabilize the bonds between the macromolecules of the cytoplasm, thus destroying thixotropy, also suppress the protoplasmic streaming. This streaming therefore appears to be connected with the thixotropic properties of the cytoplasm. We have shown that mere penetration of free water into the cytoplasm also prevents streaming, and it is thus clear that the thixotropic properties are closely bound up with the physico-chemical state of the water in the living substance.

The physiological activity of the cell continually changes its equilibrium relations: with the external medium, with inert regions such as the vacuoles, and between the colloidal phases of the living substance. This instability is characteristic of life itself, and it would be desirable to study the mechanics of the molecules directly. Unfortunately, these are submicroscopic processes, and up to the present have been susceptible of no more than indirect observation. Among them, we have seen that morphological changes in the chondriosomes sometimes reflect the physiological evolution of the cell. We shall describe some cases where an interpretation is possible.

THE EFFECTS OF WATER ON THE ROOT CELLS OF CHICORY (*Cichorium intybus*) [6, 10]

Mitochondrial preparations from the parenchyma of the tuberous root of *C. intybus L.* contain large cells with normal chondriosomes (figure 1). If, however, fragments of tuber are previously immersed in water for three to twelve hours, the appearance of the chondriosomes is quite different. Instead of granules or short filaments, they form long branching filaments, which may be associated with vesicular elements (figure 2). Examination suggests that the normal chondriosomes have come together during immersion, and have joined up at their extremities. The long, branching filaments are distinctly heterogeneous; some preparations show alignments which are too numerous to be a chance effect, and which clearly form a prelude to the joining processes.

In spite of these considerable changes, the cells can continue to live actively. In fact, if we make tissue-cultures from fragments treated in this way, we find that the fragments proliferate *in vitro*. Further, during the first few days of culture the large chondriosomes disintegrate, and most of the cells return to a normal structure (figure 3) [11].

The observed changes are thus reversible. To study them further, fixed and stained preparations are inadequate, and we have been able to explain them only by means of observation and experiment on living cells. Experimentation is made easier by the remarkable faculty of adaptation possessed by the parenchymatous cells of the root of *C. intybus*. Sections cut by hand and mounted in Ringer's solution contain, besides cells killed by the shock of sectioning, other cells, apparently unharmed, which lend themselves to the living observation of their constituents. Diluting the mounting medium with distilled water, we have been able to preserve these preparations, and to follow the changes in the constituents of one and the same living cell for periods up to two weeks [8]. Furthermore, when the Ringer's solution is replaced by pure distilled water, the cells can adapt themselves to this new medium and can survive in it for much the same period. Thus adapted, the cells form excellent material for the study of pharmacological action on living protoplasm.

During the period of adaptation, the cells immersed in pure water show some remarkable changes: active streaming of the protoplasm can be seen, and the chondriosomes remain in the form of short units carried along by the protoplasm. Many of them divide by the formation of one or more constrictions, and take on the form of a chain made up of several small granules (figure 4). Shortly afterwards, the chondriosomes hypertrophy and become less refringent; they are then more easily deformed in the cytoplasm, on contact with which they seem to show a lowered surface tension. Many become vesicular—a change known as cavulation, and one which has been considered as a sign of the approaching death of the cell and therefore irreversible.

In the present case, however, it is found that the chondriosomes slowly return to normal. The cell reaches equilibrium with the new medium and takes on its usual structure. It is then in a state of adaptation, and can be kept alive for several days. In the course of daily observation, there can be seen protoplasmic streaming (more or less active according to external circumstances) and chondriosomes of different lengths. Long chondriosomes are usually seen when protoplasmic streaming is suspended [9]. This state of affairs is difficult to bring about under the microscope, but a prolonged interruption of streaming can be effected by immersing thick pieces of tissue in pure water and taking sections after several hours of immersion. When the preparation is carried out sufficiently rapidly, large objects can be seen in the living cell, formed by the joining together, end to end, of several chondriosomes; they are similar to those seen in fixed and stained preparations. These objects are found in cells whose protoplasm is stationary, but after sectioning and illumination under the microscope streaming quickly recommences; the large branching objects can then be seen to fall apart into their constituent elements, which are chondriosomes of ordinary size. These also divide into little chains, as we have seen above, and then into small granules. It is possible, though rather difficult, to obtain large chondriosomes in sections cut without previous immersion. The preparations must be left for several days at constant temperature and in darkness or in diffused light. When these preparations are viewed under the microscope, the breaking-up of the large chondriosomes under the influence of the renewed streaming can be seen as before [10].

In sum, the immersion in water of fragments of parenchyma of *C. intybus* has the effect of stopping the protoplasmic streaming and enabling the chondriosomes to take up water, so that they join together in branching structures and make up large heterogeneous units. Normally, the formation of these structures is prevented by the protoplasmic streaming, which has the effect of dispersing the chondriosomes to an extent proportional

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FIGURE 1 – *Parenchymatous cell of* Cichorium intybus *treated by Regaud's technique, showing the chondriosomes.*

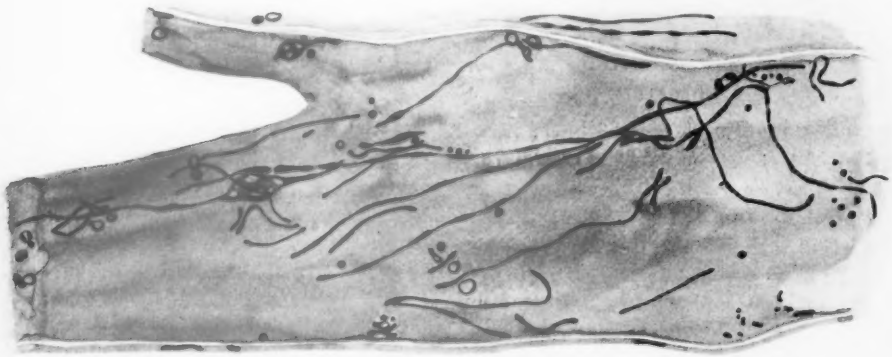
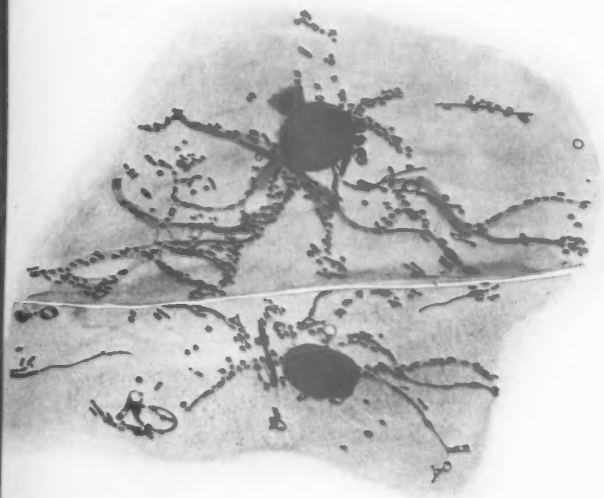


FIGURE 2 – *Cell from the same parenchyma fixed after immersion of fragments of tuber in water. Most of the chondriosomes are grouped in long heterogeneous filaments, some of which are vesiculated.*



GURE 3 – *Chondriosomes from a fragment under culture* in vitro. *The gregate is returning to normal, and the long filaments are breaking up to granules.*

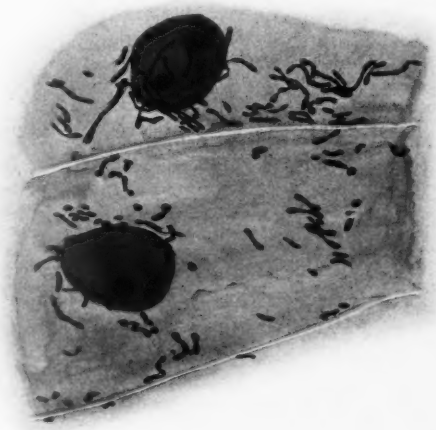


FIGURE 4 – *Granulation of the chondriosomes following accelerated protoplasmic streaming.*

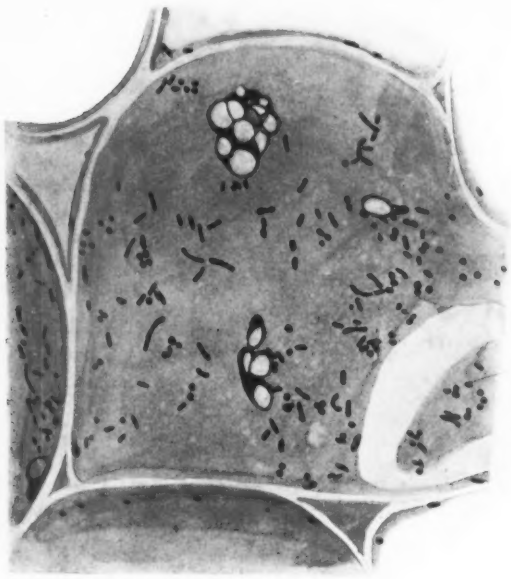


FIGURE 5 – *Motor cells from leaves of* Mimosa pudica *(from a fold of the secondary petiole). Fixed after light anaesthesia, preventing excitation; small chondriosomes.*

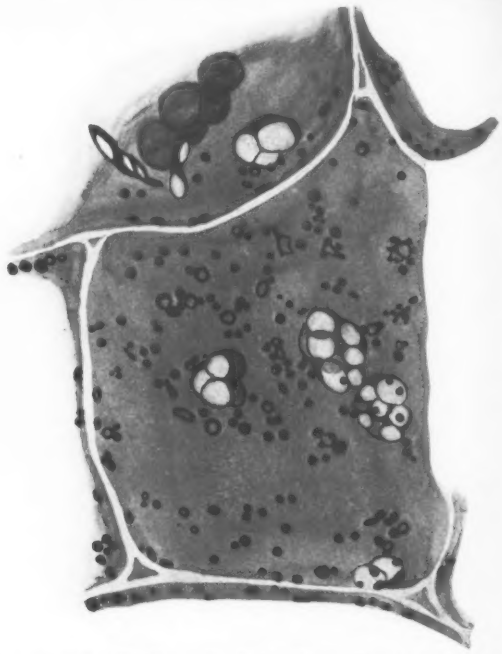


FIGURE 6 – *Similar cells fixed after mechanical excitation of the leaf; the chondriosomes are hypertrophied, granular, and partly vesiculated.*

to its activity. By experimentally changing the intensity of cytoplasmic movement, it is possible to obtain living cells with chondriosomes of different lengths, or to convert fibrillar chondriosomes into granular ones called mitochondria.

THE ACTION OF TOXIC SUBSTANCES

If cells of *Cichorium intybus* adapted to live in distilled water are placed under similar conditions in an aqueous solution of some substance or other, the effects on their chondriosomes will evidently be due to the new constituent of the medium. By this technique, Buvat and Tuchmann-Duplessis [12] have examined the action on the living cell of several toxic substances (copper sulphate, acetic acid, benzene, chloroform, etc.). Whenever the cytoplasm is affected by these substances, as can be seen by the interruption of protoplasmic streaming and by the appearance of Brownian movement and frothy structures, the chondriosomes at the same time show changes which are always alike; they resemble those produced by pure water and consist essentially in hypertrophy, granulation, and vesiculation. Here again, it seems that the changes in the chondriosomes follow the appearance of free water in the cytoplasm, the water coming in this case from the cytoplasm itself, the hydrophily of which is diminished by the toxic substances.

THE ACTION OF COLD

A physical factor, cold, produces similar effects. Matruchot and Molliard [20] showed in 1902 that frost has an effect on plant cells comparable with that of drying, in that it causes a loss of water from the protoplasm. L. Genevès [14–17] has recently confirmed this loss; the water may invade the intercellular spaces of the tissue under study. He has also described the accompanying cytological changes. Once again, the appearance of free water in the cytoplasm following the lowering of the temperature produces hypertrophy and vesiculation of the chondriosomes. Genevès has distinguished profound, irreversible changes from others which are reversible in that the cells may regain their normal structure at a low temperature, or may recover on returning to ordinary temperatures after further changes during the warming period. Thus, as well as demonstrating irreversible changes, Genevès has shown that the chondriosomes can be caused to vary their shapes or stain-reactions

reversibly by varying the relations between the water and the cytoplasm without killing the cell. We now give an example of these changes in a case of normal physiological function.

THE CHONDRIOSOMES OF THE MOTOR ORGANS OF *Mimosa pudica L*

The leaves of *M. pudica L* [7] possess three systems of folding organs sensitive to slight mechanical stimuli. The folding mechanism has been explained by the movement of water in the motor cells; the water may leave the cytoplasm or return to it, thus causing variations in the rigidity of the sensitive tissue. This interpretation has led us to study the behaviour of the chondriosomes during the folding process. Briefly, we have been able to show that they are normally small and granular, but become hypertrophied and partly vesiculated in the excited cells (figures 5 and 6). This suggests that the excitation causes the appearance of free water in the cytoplasm.

SHAPES OF THE CHONDRIOSOMES

From the above facts, we conclude that the morphology of the chondriosomes is very sensitive to changes in the state of the water in the living cytoplasm. The factors which alter the shapes of the chondriosomes seem usually to act by modifying the bonds between the water and the macromolecules of the cytoplasm. This experimental study shows also that the chondriosomes are essentially heterogeneous, and are built up linearly from elementary granular particles similar to the *grana* in the plastids described by Heitz [18, 19], Beauverie [1–4], and others. When isolated, the granules form mitochondria, but they can join together to build up fibrillar chondriosomes and, conversely, these can break down into mitochondria.

We may view these facts in the light of classical ideas on the evolution of chondriosomes during differentiation. The chondriosomes are small and granular in active meristematic cells, but are often elongated into filaments in differentiated cells approaching senility. It seems probable that the long fibrillar chondriosomes found in old cells are not the result of an elongation of the chondriosomes of young cells, as has often been supposed, but are the result of their joining together end to end. More exactly, we may say that in active cells with intense protoplasmal streaming the chondriosome material is usually dispersed in the form of small units, whereas in cells whose protoplasm moves slowly, such as senescent cells, the natural tendency of the chondriosomes to join together is not prevented. This explains the long fibrillar chondriosomes which are often present in degenerating cells.

It thus seems that the motion of the cytoplasm plays an essential part in determining the shapes of the chondriosomes. The appearance of free water in the cytoplasm, which inhibits protoplasmic streaming and which is taken up by the chondriosomes, tends to facilitate their joining together, while an increase in protoplasmic movement tends to disperse them. By varying these two factors experimentally, it is possible with certain cells to control the shapes of the chondriosomes within the limits imposed by the necessity of keeping the cells alive.

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Bacterial polysaccharides

M. STACEY

Bacterial polysaccharides form part of the cell-building material, and also occur on the cell surface. They are important in medicine as immunizing and diagnostic agents, and derivatives of one of them are finding increasing use as a blood-plasma substitute and a blood anticoagulant. In soils, bacterial polysaccharides are important as moisture conservers. Their structures are highly complex, and investigations in this field have revealed an important relationship between chemical constitution and serological specificity.

During their life-cycle, all bacteria produce relatively large quantities of polysaccharide material [1]. These natural macromolecules occur in the cell cytoplasm, functioning as cell-building material or stored in pockets as a food or energy reserve, or they may be found on the cell surface as a slimy, protective layer which bacteriologists term a capsule. The capsule varies in thickness under different conditions of growth, and with different organisms. Frequently it breaks away from the cell surface, and its components may be found dissolved in the solution in which the cells are growing. Bacteriologists visualize [2] some individual cells as depicted diagrammatically in figure 3.

When the bacteria are cultivated in colonies, capsular material can often be vividly demonstrated. Thus in figure 1 [3] is shown a colony of a strain of a streptococcus growing under ideal conditions on a sucrose-agar medium from which large quantities of a polysaccharide known as a fructosan can be obtained simply by extraction with water. Figure 2 shows the same strain of streptococcus growing under conditions in which sucrose and magnesium have been excluded from the medium. No fructosan can be isolated from such a colony, and microscopic examination of the individual cells reveals that they are not encapsulated. In pathogenic micro-organisms, the capsule acts as a first line of defence of the cell against attack by phagocytes, and it appears to combine immediately with homologous immune proteins or antibodies. Capsule-formation is very much in evidence when the bacteria are highly infective and virulent. In encapsulated soil bacteria, such as certain nitrogen-fixing types, some capsular material may frequently diffuse away from the cell; it probably acts as a defence against soil protozoa.

Enzymes, too, may be liberated by bacteria, and when conditions are favourable may synthesize extra-cellular polysaccharide material. In polysaccharide production, there is a good deal of overlap between animal, plant, and microbial cells. Thus animals, bacteria, and a few plants all produce glycogen, while bacteria and plants

FIGURE 1 – *A strain of streptococcus growing on sucrose-agar medium under ideal conditions. Large quantities of fructosan are produced, and capsules form on the cells. (By courtesy of The Royal Society.)*

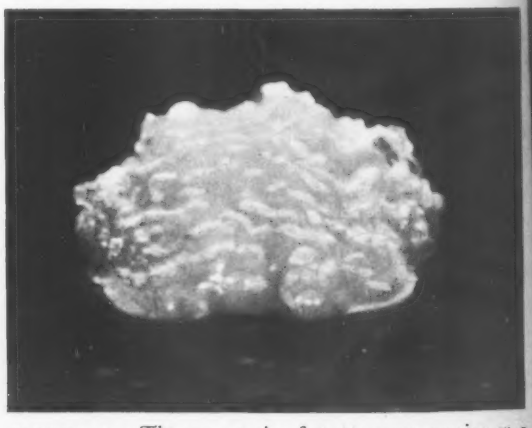

FIGURE 2 – *The same strain of streptococcus growing on a medium from which sucrose and magnesium have been excluded. No fructosan is formed, nor are there capsules round the cells. (By courtesy of The Royal Society.)*

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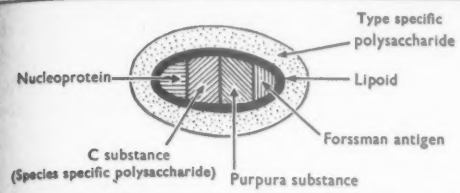


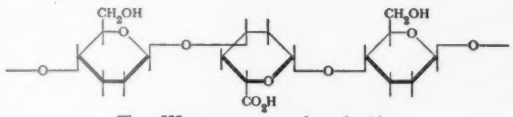
FIGURE 3 – *Diagrammatic representation of the constitution of a bacterial cell and its capsule. (By courtesy of Charles C. Thomas, slightly modified from 'Agents of Disease and Host Resistance,' by F. P. Gay* [2]).

produce cellulose and starches, hyaluronic acid, and so on. Researches on the fundamental characteristics of bacterial polysaccharides have resulted in important medical applications for them. One of the most exciting achievements concerns the immunologically important polysaccharides of the variety of *Pneumococcus* which is a cause of lobar pneumonia.

Before 1917, none of the chemical constituents of the pneumococcus had been examined. In that year, Dochez and Avery [4] of the Rockefeller Institute discovered certain soluble substances in the blood and urine of patients suffering from lobar pneumonia, and showed that these substances occurred also in filtered cultures of pneumococcal cells, and in the blood of animals experimentally infected with the pneumonia-causing organisms. In very dilute solution, e.g. 1 in a million, the substances gave a specific precipitate with immune serum from animals or humans infected with the same type of pneumococcus. It was quickly shown that pneumonia could be caused by many different types of pneumococcus, and that each type when injected, alive or dead, into animals could generate antibodies giving very strong specific precipitates *in vitro* with homologous soluble substances. They were also shown to give weaker reactions (cross-precipitin reactions) with soluble material from certain other heterologous types, and from related bacteria. Avery and Heidelberger in 1923 made the important discovery that the soluble specific substances (S substances) were polysaccharides originating from the capsule of the pneumococcus cell. Heidelberger and his colleagues then studied the isolation and chemical characteristics of the specific polysaccharides from *Pneumococcus* Types I, II, III, IV, etc., and their data show remarkable differences in chemical composition and in some physical properties. The known pneumococcal types now number over 70, and each possesses a structurally different capsular polysaccharide. In addition, there is one species-specific polysaccharide, termed the C or somatic polysaccharide, which is common to all types.

All the specific polysaccharides form viscous solutions in water, and are macromolecules with very large molecular weights; some characteristic figures are shown in the table on p. 40.

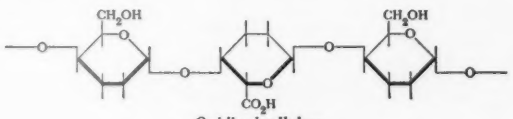
The high frictional ratio as measured in the ultracentrifuge indicates a cylindrically shaped macromolecule. The chemical architecture of the Type III material was determined with some precision by W. F. Goebel and his associates [5], who suggested the formula:



Type III pneumococcus polysaccharide

The polysaccharide is made up of cellobiuronic acid residues linked through the third carbon atom in the glucuronic acid moiety to the first carbon atom in the next glucose unit, giving a long chain structure which contains alternate linkages of the type already known in the cellulose molecule. Cellobiuronic acid and glucuronic acid are both special types of oxidized sugars.

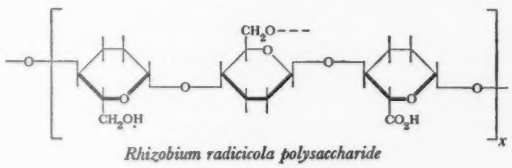
Study of the occurrence of the acidic disaccharide repeating unit, which is the cellobiuronic acid, has brought out a remarkable relationship between structure and serological specificity. In many cases where there is a cross-relationship in the serological sense, the polysaccharides all possess closely related acidic disaccharide structures; thus Type VIII pneumococcus polysaccharide is another variety of polymerized cellobiuronic acid. From these discoveries, Heidelberger was able to make the striking prediction that mildly oxidized cellulose



Oxidized cellulose

would cross-react with Types III and VIII pneumococcal antisera.

Capsular polysaccharides from non-pathogenic



Rhizobium radicicola polysaccharide

Molecular weight and frictional ratio of Pneumococcus *polysaccharides as determined by the ultracentrifuge method*[1]

Type	*Sedimentation*	*Diffusion*	*Molecular weight*	*Frictional ratio*	*Axial ratio*
I	6·5	2·00	171,000	3·2	60
II	7·2	0·75	504,000	6·0	200
III	4·3	1·60	141,000	4·3	110

nitrogen-fixing soil organisms, e.g. *Rhizobium radicicola* and *Azotobacter chroöcoccum*, cross-react with certain types of pneumococcal antiserum, and they also possess glucose-glucuronic residues as building units. Similarly, an acid-containing polysaccharide from gum arabic, with a structure somewhat related to that of the Type III material, will give a cross-reaction with pneumococcal antiserum.

We have recently shown that the Type II specific polysaccharide contains building-units made up of rhamnose, glucose, and glucuronic acid, the repeating pattern of the macromolecule being of the branched-chain type. The glucose units form the main branching points, linkage occurring through the first, fourth, and sixth carbon atoms. This discovery is of potential importance, since some of the dextran polysaccharides mentioned below, which are useful as blood-plasma substitutes, give cross-reactions with Type II and Type XX pneumococcal antisera. In one of the dextrans, glucose forms a branching point identical with that in the Type II polysaccharide. During recent years, Heidelberger and his associates showed in extensive field trials (figure 4) [6] that the pneumococcal polysaccharides could be used as prophylactic vaccines, and that the incidence of pneumonia could be notably lessened by combining a number of types.

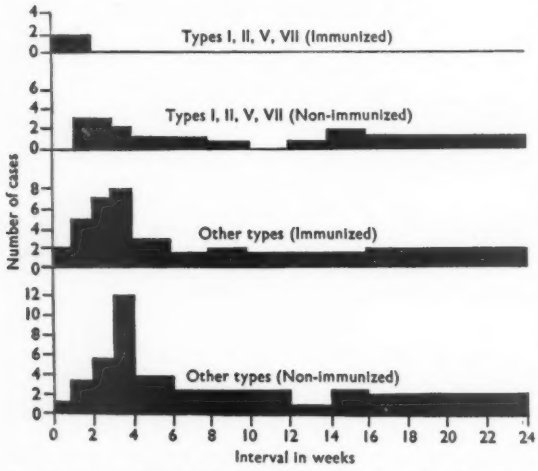

Types I, II, V, VII (Immunized)
Types I, II, V, VII (Non-immunized)
Other types (Immunized)
Other types (Non-immunized)
Number of cases
Interval in weeks
0 2 4 6 8 10 12 14 16 18 20 22 24

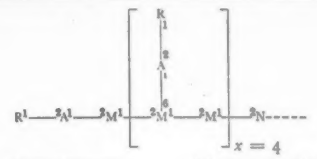
FIGURE 4 – *Immunizing effect of pneumococcal polysaccharides derived from pneumococci of various types. The incidence of pneumonia can be notably diminished by combining a number of types. (After Heidelberger.)*

[1] Record, B. R. and Stacey, M. *J. chem. Soc.*, 1561, 1948.

It has recently been demonstrated by Avery and his colleagues that the transformation of one type of *Pneumococcus* into others can be effected *in vitro* [7]. Thus, Type II cells grown under conditions in which they are found as unencapsulated rough (R) forms were treated with a certain fraction from an extract of Type III encapsulated smooth (S) forms. As a result, the Type II R was transformed into a Type III S, with all the hereditary characteristics of this type. The transforming principle was shown to be a deoxypentosenucleic acid, which apparently combined with a protein at the surface of the Type II R form, giving an enzyme synthesizing a Type III polysaccharide. The power to form this particular enzyme was transmitted to daughter-cells, and the discovery therefore provides an authentic case of a specific mutation caused by a chemical entity.

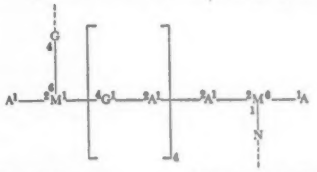
There is an unusual immunological relationship between the pneumococcus Type XIV capsular polysaccharide and certain surface components of human red blood-cells. Injection of this polysaccharide into the horse gives rise to an antiserum which causes agglutination of the red cells of all the four main blood-groups. Certain fatal reactions observed some years ago, following the use of the Type XIV pneumococcus antisera, appear to have arisen from this unusual cross-reactivity with erythrocytes. The Type XIV polysaccharide contains N-acetylglucosamine and galactose units, and it is significant that substances having the properties of blood-group factors, which may be extracted from erythrocytes and various tissues, are polysaccharides containing N-acetylglucosamine, galactose, and fucose units. Mild acid hydrolysis of a factor of blood-group A removes fucose-residues from the ends of chains of macromolecules and diminishes the blood-group activity, but nevertheless considerably increases cross-reactivity with Type XIV antiserum.

From the immunizing point of view, the most important polysaccharides are found as components of the heterophile immunogens of certain Gram-negative bacteria, such as the *Salmonellae* which cause food-poisoning, dysentery, typhoid



R *represents L-rhamnopyranose.* M *represents D-mannopyranose.*
A *represents D-arabofuranose.* N *represents an amino-hexose.*
(*The figures show the points of attachment.*)

FIGURE 5 – *Somatic tuberculosis polysaccharide*



A *represents D-arabofuranose.* M *represents D-mannopyranose.*
G *represents D-galactopyranose.* N *represents D-glucosamine.*

FIGURE 6 – *Lipid-bound tuberculosis polysaccharide.*

fever, and so on. They were discovered simultaneously by Raistrick and Topley [8] and by Boivin and Mesrobeanu [9]. Raistrick and Topley disrupted the bacterial cells by tryptic digestion, thereby liberating the polysaccharide into aqueous solution; Boivin and Mesrobeanu achieved the same effect by treatment with trichloroacetic acid. The immunizing agent in each bacterial species was composed of a polysaccharide linked up with phospholipids and amino acids. Extensive studies were carried out by Morgan [10] on *Bacterium shiga*, which causes dysentery. The chemical structure of this type of bacterial polysaccharide remains to be studied, but N-acetylhexosamines, galactose, and sometimes mannose and rhamnose, were shown to be important components of the macromolecules.

Numerous polysaccharides have been isolated in large quantities from the *Mycobacteria*, some of which are the causes of tuberculosis, leprosy, and other diseases. These polysaccharides frequently show serologically specific reactions against antisera, but they do not appear to possess any power to immunize animals against infection. Furthermore, differences in chemical composition and structure do not cause marked changes in specificity.

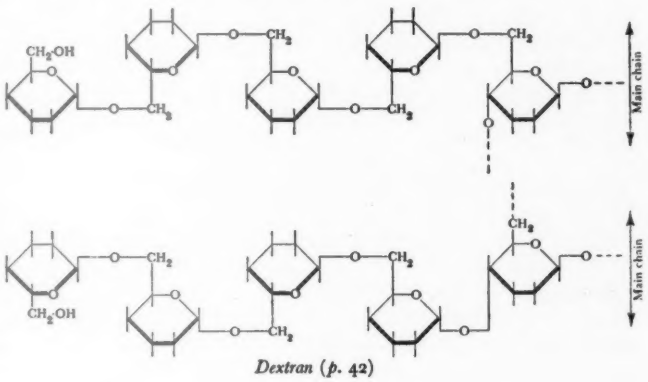
Some strains of *Mycobacterium tuberculosis hominis*, which is a cause of human tuberculosis, build up a glycogen indistinguishable from the glycogens of animal tissues, yeast, and other microorganisms. A polysaccharide closely related to glycogen occurs in the culture fluid in which *M. tuberculosis* is grown. It contains only glucose units, and is closely bound to a fatty substance. Two polysaccharides from the bacterial cells—one from a waxy surface material and one from the somatic region—have been examined in some detail. The general pattern of their molecular structure is shown in figures 5 and 6 [11]. They are highly complex branched-chain systems. A striking feature about them is their content of the pentose sugar *D*-arabinose, which was found for the first time in nature in the five-atom ring (furanose) form. There is a good deal of evidence to show that highly virulent forms of *M. tuberculosis* possess a slime-layer of material containing polysaccharides and fats.

The Type I meningococcus, a cause of human meningitis, contains a polysaccharide which is a poor immunizing agent but remarkable for its high content of phosphorus.

Very many important bacterial polysaccharides have been isolated from a large number of other pathogenic bacteria, and have been well characterized, but their chemistry awaits investigation. Prominent among them are products from the anthrax bacillus, from the cholera vibrio, from *Brucella* (which causes Malta fever), and from streptococci and staphylococci (which cause boils, skin infections, etc.). The polysaccharides have been most useful in diagnostic tests, in skin reactions, and in the study of anaphylaxis. A certain bacterial polysaccharide has been indicted as a pyrogenic substance which causes a mild fever, and must therefore be carefully removed from all pharmaceutical preparations.

POLYSACCHARIDES FROM NON-PATHOGENIC BACTERIA

The slimes of stagnant water, decaying vegetable matter, and the like are familiar to everyone; they are often caused by microbial action.



Dextran (*p.* 42)

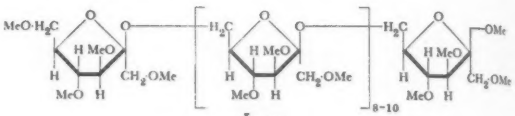
Probably the first bacterial polysaccharide ever to be described and characterized was the substance called dextran [12]. This name is now applied to a group of polyglucoses produced from cane or beet sugar by *Leuconostoc* species, which are related to the streptococci; they cause the ropiness which is often a nuisance in sugar refineries.

Dextrans are water-soluble macromolecules having a high optical activity: $[\alpha]_D \simeq +200°$. They have come into prominence during recent years because their molecules may be adjusted to produce a degraded product which, in 6 per cent. physiological salt solution, can be used as a blood-plasma substitute. The chief characteristic of dextrans is the high proportion of linkages which engage the first and the sixth carbon atoms in each glucose unit. They have molecular weights of the order of a million or more, and their chain molecules may be straight or branched.

The blood-plasma substitute is made by degrading the macromolecule by acidic hydrolysis, enzymes, or supersonic sound-waves. A fraction is selected having a molecular weight of the order of 70,000–90,000. This has the correct colloid osmotic pressure, density, and viscosity for infusion into patients where there is a need to replace blood, e.g. after haemorrhage, burns, or shock.

Degraded dextran is non-immunizing, and altogether is a bland substance in the body, from which it is removed completely within a few days. The preparation being made in Britain at the present time on a large scale is synthesized by the 'Birmingham' strain of *Leuconostoc mesenteroides*, and possesses a highly branched structure containing normal linkages with additional cross-linkages. An enzyme system which makes dextran *in vitro* has been isolated; it appears to contain both chain-forming and chain-branching enzymes.

Some non-pathogenic *Streptococcus* strains when grown on sugar reject the glucose, and convert the fructose moiety into a polyfructose termed a levan. Many of these levans have been carefully studied; they contain the same type of molecule, with linkages at carbon atoms 1 and 2.



Levan

Many levans are formed by bacteria which are pathogenic to plants, e.g. *Bacillus pruni*, but their possible significance in plant diseases is not yet understood. The organisms which cause a kind of tumour in plants, such as *Phytomonas* species, produce an unusual polyglucose when grown on cane sugar. Bacteria which inhabit soils can produce viscous polysaccharides such as levans and dextrans, and are of importance in aggregate-formation and moisture-conservation in soils.

Bacterial polysaccharides are of potential importance in various other ways. Thus a polysaccharide produced by *Serratia marcescens* has been studied extensively because of its power to cause regression of certain tumours. It appears that the polysaccharide has a profound effect on the nuclei of some tumour cells. Some bacterial polysaccharides have a specific retarding influence on virus-multiplication, as with the pneumonia virus of mice.

Bacterial cellulose is most important, as it is identical in physical and chemical properties with cotton cellulose. *Acetobacter* species synthesize it from many carbon sources; it is useful for studying cellulose synthesis.

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Pharmacological aspects of chemicals in food

A. C. FRAZER

Chemicals are used in the manufacture of many foods, to maintain or improve good qualities; they may also occur in food owing to accidental contamination. There has been prolonged controversy as to the wisdom and safety of the deliberate use of chemicals in food; in the present article Professor Frazer, a leading authority on the subject, advances the view that, subject to careful experimental investigation and reasonable control, the practice is not deleterious to health and is valuable for the conservation of the world's food supplies.

THE OCCURRENCE OF CHEMICALS IN FOOD

Chemicals in food fall into two groups—food adulterants, with which food may become accidentally contaminated, and food additives, which are purposely added for technical reasons. The chemicals with which food may become adulterated include a number of potentially poisonous substances, such as insecticides sprayed on fruit and vegetable crops, detergents used in washing food-containers, greases used for baking-tins, or lubricants for machinery. Clearly, the potential toxicity of these various substances must be investigated, and safety limits determined and enforced [1]. Food additives, with which this article is mainly concerned, present a rather different problem. They are essentially non-toxic substances used to maintain or increase desirable properties in foods. Relatively few foods are eaten in the natural state, some preparation or processing being usual. When this is done on a large scale, chemical treatment may be the most effective way of making the material uniform and satisfactory for use. Thus, flour is commonly obtained from many different sources, and each type of flour may vary in composition and properties. It is desirable that flour used for bread-making should have some reasonable uniformity of characteristics, or at least predictable qualities. This condition can be achieved at the mill by appropriate blending and treatment. Some of the properties required can be obtained by allowing the flour to age, but the storage problem involved in ageing flour for even a few weeks makes this method of treatment impracticable. Fortunately, similar effects can be induced immediately by treatment with certain chemical substances such as nitrogen trichloride ('agene') and chlorine dioxide. Ascorbic acid also can be used. The quality of the bread can be further improved by the use in the bakery of other chemical agents, such as potassium bromate, propionic acid, and various esters of fatty acids and alcohols. These substances improve crumb-quality, control mould-formation, and delay staling [2]. The use of chemicals in bread has naturally received special attention because of the importance of bread in the human dietary. Chemicals are extensively used, however, in many other foods. Thus, oxidative changes in fats may be controlled to some extent by the use of anti-oxidants [3], although this is not at present permitted in Britain. Many other substances, such as emulsifiers, stabilizers, sweetening agents, and dyes find their place in food manufacture. The use of food additives has greatly increased in the last twenty years, and there is every indication that they will be much more extensively developed in the near future. There is good reason for encouraging the development of food technology, since it helps us to make the most of the world's inadequate food supplies.

THE DANGER

The addition of either natural or synthetic chemicals to food carries a potential risk to the consumer if the pharmacological action of the substance in this dietary context is not known. Synthetic chemicals are no more likely to be toxic than natural substances—indeed, many of the most potent poisons known are of natural origin. Substances that have been consumed as food for centuries are not necessarily harmless, since millions of people have died from unknown causes over the same period. In fact, there is ample evidence to indicate that certain foods can cause harmful effects. Some people are allergic to particular articles of diet, and may develop alarming symptoms after eating them even in small quantities. Wheat-gluten has recently been shown

to be deleterious to children with coeliac disease [4, 5]. Dietary characteristics may account, at least in part, for differences in the incidence of such conditions as cirrhosis of the liver [6] and atherosclerosis [7]. Thus, many natural constituents of the diet may have harmful potentialities. The diet must be regarded as a part of the environment of man, and one of the factors that may determine the life-span of the individual. The problems of chemicals in food fall into their proper perspective when examined against this broader background.

The discovery by Mellanby [8] that agenized flour can cause running-fits in dogs, and similar toxic effects in rabbits and ferrets, has focused attention on the problems of chemicals in food. The simple lesson to be learnt from Mellanby's experiments is that, in future, all food additives should be adequately investigated before being brought into general use. Mellanby's studies showed that the suitability of animal investigations for this type of work cannot be questioned, since he demonstrated the toxic effect of agenized flour by means of well-established biological methods using standard laboratory animals. It should also be noted that agenized flour has no detectable effect on man [9, 10], and the same applies to all the common foods with additives. Indeed, the general level of health of the people of Britain has improved over the same period as that in which food additives have been so extensively used—though of course no-one would claim to have established a connection between the two. Alarmist statements about the use of chemicals in food may, therefore, be discounted as lacking factual basis. Nevertheless, reasonable people agree that any potential risk, however slight, must be kept under review by those responsible for the maintenance of proper health standards. There is no need to suggest that the use of all chemicals in food manufacture should be forbidden, even if such extremist action were a practical solution, since the problems raised by the use of chemicals in food can be solved along more rational lines.

THE SAFEGUARD

The direct or indirect effects of any food additives on biological systems may be adequately assessed by the application of appropriate pharmacological methods, based on adequate knowledge of the biochemical properties of the substance under test, and a full appreciation of the nutritional implications [11]. The substance under investigation must be characterized chemically and the standard of purity specified. A publication, somewhat similar to the 'British Pharmacopoeia,' giving the specifications for acceptable food additives, may be necessary to ensure that the chemicals actually used in food treatment are the same as those tested and approved. The chemical and physical properties may clearly indicate certain likely toxic effects, but this is mainly of academic interest, since any action of the substance, predictable or otherwise, can be determined by normal pharmacological methods. Any significant response observed should be quantitatively related to the effective dosage level; the dose required to cause any particular effect in 50 per cent. of a group of experimental animals is termed E.D.50.

The importance of relating pharmacological effects to dosage cannot be over-emphasized. Dosage levels of all chemical substances can be roughly classified, from a pharmacological point of view, as ineffective, effective, toxic, and lethal. With most common drugs, the general ratio of ineffective, effective, toxic, and lethal dosage in man is not greater than 1 : 10 : 100 : 1000. Thus, the therapeutic dose of atropine for an adult of about 70 kg body-weight is of the order of 1 mg, the toxic dose is 10 mg, and a likely fatal dose 100 mg. The administration of 0·1 mg to an adult man is unlikely to cause any demonstrable effects. Similar relationships are found in the case of arsenic, the therapeutic dose of which is of the order of 5 mg, the toxic dose about 50 mg, and a likely fatal dose about 500 mg. An ineffective level of dosage is 0·5 mg, and this is the same order of dosage that may result from the ingestion of arsenic in food within the accepted limits of tolerance. Dosage has a direct relationship to body-weight. Thus, other things being equal, the same effect will be produced in an infant of six months weighing 7 kg by one-tenth of the dose that is effective in an adult man of 70 kg. Consequently, the consumption of one-tenth of an ineffective adult dose by a six-months-old infant does not bring the dosage level outside the ineffective range.

This question of dose-response relationships is vitally important in deciding both the design and the interpretation of the pharmacological studies. In the study of therapeutic agents it is important to define the effective level, but in the study of food additives attention must be directed to the establishment of the ineffective dosage level and the provision of an adequate margin of safety for this estimate. Food additives may cause no demonstrable effects in experimental animals, even when

administered in a dose of 1 g per kg body-weight. Substances with an ineffective dosage level of this order are usually regarded as non-toxic. With food additives, it is necessary to relate dosage levels to the daily intake of the substance. This quantity may be termed the standard dietary dose, and should take into account any likely variation in quantities used. The question now arises of the level at which feeding-tests should be carried out. It has been agreed on a more or less arbitrary basis that food additives should be tested at various dosage levels up to 100 times the standard dietary dose. It has not been clear, however, how the results of such tests should be interpreted; some authorities demand that no effects should result from the hundredfold test-dose, while others have not accepted substances that conform even to this rigorous criterion, and still others have suggested that substances should be rejected on the basis of invisible and undemonstrable changes that may have occurred. This last view denies the whole basis of observational and experimental science, and clearly makes any form of biological testing otiose. If the general question of dose-response relationships is considered, the results of the investigation of any substance at ten times and a hundred times the standard dietary dose can be reasonably interpreted. If the substance causes no effects at the tenfold dosage, and significant effects in less than 50 per cent. of the experimental animals at the hundredfold dosage, the standard dietary dose should be regarded as acceptable, since it is clearly less than one-tenth of the ineffective dose and one-hundredth of the E.D.50, with regard to any significant action of the substance under test. Should any significant effect of the substance be demonstrated at the tenfold dosage, or in more than 50 per cent. of the animals at the hundredfold level (nutritional and palatability effects being excluded) the E.D.50 should be estimated, and from this the appropriate level of acceptance can be calculated. These various dosage relationships are indicated in table I. As already mentioned, most of the food additives have been found to be essentially non-toxic, so that the dosage levels usefully studied do not go further than the effective dose. If substances should have to be considered which give toxic or lethal effects at doses of less than 1 g per kg body-weight, a detailed study of the dose-response relationships of the particular substance under test would be advisable.

The possible effects of the food additive must be studied in both short-term and long-term experiments. This is readily achieved by carrying the feeding experiments through several generations, and examining the effects throughout the life-span of the animal. If there is any indication that cumulation might occur, the maximum weight of the substance eliminated in 24 hours should be determined. From these data, the non-cumulative dosage level can be accurately assessed, provided that the organs responsible for elimination are not damaged by the substance, and that this eventuality has already been guarded against by the toxicity tests.

Finally, the studies must be made in several different species of animal. True species-specificity with regard to the action of chemical substances is not common, although considerable differences may occur in the effective dosage level in relation to body-weight. Results

TABLE I

Suggested dose relationships for the interpretation of toxicity tests

Dosage group	*Result*	*Quantitative data required*	*Approximate acceptable dose relationships*
Lethal	Death	Lethal dose 50	10,000
Toxic	Demonstrable tissue damage	E.D.50	1,000
Effective	Significant modification of structure or function	E.D.50	100
Ineffective	No significant change in structure or function	No significant differences as compared with controls	10 — Common range for food additives
Acceptable dietary level[1]	—	—	1

[1] This acceptable dietary level is expressed in mg/kg body-weight, and the actual figure in each case must be related to the standard dietary dose, which may be expressed as parts per 1000 of the total diet for a 70 kg (150 lb) man.

observed in experimental animals are generally applicable to man. It is wise, however, to carry out a test in human subjects after non-toxicity has been established in animals, to exclude any unexpected species-specific effect.

Indirect toxicity may be of two types, one due to interaction of the chemical with some other food constituent, producing a toxic agent, and the other due to interference with the nutritional properties of the food. The formation of a toxic substance can be studied by the methods used to establish the presence or absence of direct toxic action, but in this case the treated food material must be used for the test. From the dosage point of view, it should be sufficient for the material to be studied at the normal and ten times the normal levels of treatment. If some toxic effect can be demonstrated, the precise nature of the deleterious agent should be determined, if possible, and the E.D.50 measured. This, of course, was done in the case of agenized flour, when the toxic agent was found to be methionine sulphoximine [12].

The other possibility is that the food additive causes some damage to the nutritive value of the food. The processes used in the preparation of food commonly modify nutritional properties, the effect of cooking in this respect being well known. The reduction of some specific nutrient in one article of the diet is not necessarily serious, since with a normal mixed diet the essential nutrients are drawn from a number of different sources. Similarly, slight reduction in calorie-value cannot be regarded as significant. While the consumer may add up the calories in his diet with apparent accuracy, the result bears only an approximate relationship to the actual calorie-value of the food passing into the body, since the efficiency of absorption, extent of digestion, and modification by intestinal organisms may affect the actual supply of calories. In general, calorie-intake is mainly determined by appetite and supply, assisted under the somewhat artificial conditions of human existence by experience, food-tables, and regard for body-weight. Changes in essential nutrients are also likely to be unimportant, since, as already mentioned, essentials are normally included in several different foods. In general terms, the more sophisticated the diet, the greater is the individual choice, and the more adequately are the essential nutrients covered. More trouble from interference with nutrients in a single article of food might be expected to arise if it formed a major part of the more monotonous and restricted diet consumed by primitive peoples or by certain food faddists. However, even though this problem may not be very serious, it seems advisable that the effect of food additives on the nutritional value of the diet should be known. Any gross effects will be shown up by defective growth-curves in the investigations suggested for the study of possible toxic factors, and more precise information with regard to essential nutrients can be readily obtained by direct measurement of these substances before and after chemical treatment.

It may therefore be concluded that the careful biological investigation of food additives can provide an adequate safeguard against the risks that are inherent in all new technical procedures. The general principle should be followed of direct measurement of known factors by appropriate chemical or physical methods, and biological assay of unknown factors. Dose-response relationships must be taken into account in all these toxicological problems. The effectiveness of the safeguard provided by these various studies increases with the scope of the relevant knowledge available. For this reason, research in the general field concerned with the relationships of diet, nutrition, and health should be encouraged.

TABLE II

	Average level of treatment in parts per million	*Properties*	*Action*	*Residue*
Nitrogen trichloride ..	60	Gas	Improves and bleaches	None
Chlorine dioxide ..	30	Gas	Improves and bleaches	None
Benzoyl peroxide ..	15	Solid	Bleaches	Benzoate
Potassium bromate ..	20	Solid	Improves	Bromide
Ammonium persulphate	160	Solid	Improves	Sulphate

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FLOUR IMPROVERS

A number of substances are used in the treatment of flour, as already described. These are mainly oxidizing or reducing agents, and their action is to modify the properties of the flour protein. Some representative members are listed in table II.

It will be seen that the quantities involved are small, and that the risk of direct toxic action is therefore negligible. The obvious dangers are indirect toxic effects due to the production of toxic agents, or impairment of nutritional properties of the flour. Nitrogen trichloride has been mentioned above as producing methionine sulphoximine, which causes running-fits in dogs, ferrets, and rabbits [8]. The amount consumed by a man each year is extremely small, and well within the ineffective dosage range. It is, however, a debatable point whether the margin of safety is wide enough in this case. The other members of this group do not form methionine sulphoximine, nor have they been shown to form any other toxic agents. Their effects on the nutritional value of the diet have been shown to be negligible. On the evidence at present available, all these agents, with the possible exception of nitrogen trichloride, would appear to be acceptable.

BREAD IMPROVERS

In addition to flour improvers, various substances are used in the bakery to prevent staling and to improve crumb quality. Three particular substances may be mentioned: glyceryl monostearate, stearyl tartrate, and polyoxyethylene stearate. The standard dietary dose proposed in bread in mg/kg body-weight per day is 7, 3, and 35 respectively. From the direct toxicity point of view, no effects from any of these compounds can be demonstrated in rats with dosage levels up to 100 times the standard dietary dose in long-term experiments. Indirect toxic effects could not be demonstrated at ten times the normal level of treatment. The substances have been tested in several species, including man, and no gross species differences were found. No significant damage to nutritional value occurs at the dosage levels considered. The available evidence therefore indicates that these three compounds should not be harmful to health if used in the quantities proposed.

The chemical substances used in bread represent the most difficult problem that arises in connection with food additives, since bread is such an important article of the diet, commonly eaten every day by hundreds of millions of people. The solution of these bread problems, which is now largely achieved, will open the way to a more enlightened appreciation of the general question of chemicals in food improvement and conservation.

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John William Mallet, 1832–1912

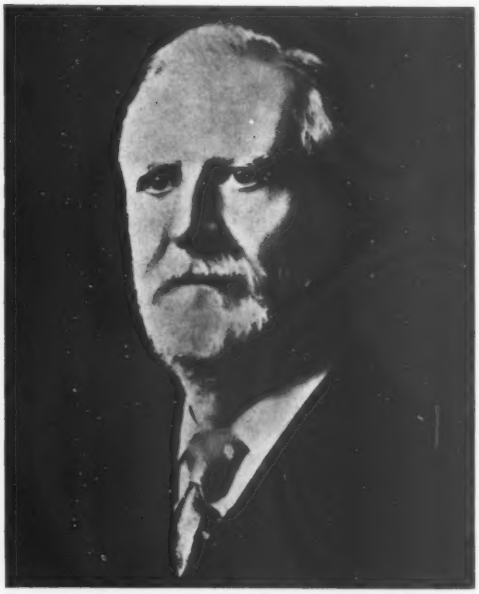
DESMOND REILLY

Though John William Mallet, an Irish-born chemist, attained in later life considerable distinction in scientific circles in America, little has been written about him except in the United States. His career was a varied and interesting one, and his chemical work deserves to be better known. He was a Fellow of the Royal Society (1877), Vice-president of The Chemical Society (1888–90), and President (1882) of the American Chemical Society.

John William Mallet was the son of Robert Mallet, a leading Dublin engineer and Fellow of the Royal Society [1], and was the grandson of John Mallet, a brass and copper founder who originally came from North Tawton in Devonshire, England.

Robert Mallet's wife was Cordelia Watson, and there was a family of three boys and three girls, John William Mallet being the eldest. He was born at Drumcondra House, in the northern suburbs of Dublin, Ireland, on 10th October, 1832.

It was evident that the boy inherited from his father a real interest in science. After early education by his mother and by a governess he was sent at the age of nine to a private school run by a clergyman, J. P. Sargent. Though Sargent's special enthusiasm was for the classics, he employed a young man to visit the school once a week to talk to the pupils on chemistry and physics. This young man was a brother of Samuel Lover, the Irish poet and novelist. In later life Mallet recalled those illustrated science talks with appreciation.



Portrait of John William Mallet. (From the Edgar Fahs Smith Memorial Collection, University of Pennsylvania.)

In addition to the weekly science lesson, young Mallet browsed at will in his father's extensive library, reading works by Black, Lavoisier, Fourcroy, Vauquelin, Davy, Henry, and Thomson among others. Mallet himself remarked in after years that 'reading nearly all of the volumes of Thomson's "Annals of Philosophy" was serviceable in early starting the idea that our knowledge of nature is not complete and embodied in text-books; but that it rests on observation and experiment, is constantly growing, and is always subject to modification and correction' [2].

When Mallet was sixteen, he attended a course of winter lectures on chemistry given by Dr James Apjohn [3] at the Royal College of Surgeons in Dublin. Apjohn noticed the boy's interest in science and arranged for him to take additional practical training in his private laboratory. Here he secured an excellent training in methods of analysing minerals.

At the time when Mallet's training with Apjohn was beginning, he helped his father to carry out a series of elaborate experiments on the velocity of transmission of gunpowder-explosions through various media, and assisted him also with a further project on hand at that time. This was an ambitious attempt at cataloguing all recorded earthquakes from the earliest times onwards. The final compilation [4] came to almost 600 printed pages and was entirely prepared by young Mallet, though the discussion of the material was undertaken by his father.

On entering Trinity College (Dublin University) in 1849, Mallet continued to benefit from tuition by Apjohn, who transferred from the Royal College of Surgeons to the Trinity College medical

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school at about that time. In the year that he entered college, Mallet published his first original scientific paper [5]. This dealt with a chemical examination of killinite, a mineral discovered in 1817 near Killiney, County Dublin. Mallet reported the presence in killinite of 0·5 per cent. of lithium, a constituent which had been missed in earlier analyses. Mallet's detection of lithium in the ore doubtless played a part in directing his attention some years later to a redetermination of the atomic weight of lithium [6].

In the spring of 1851, Mallet went to Göttingen to begin work in Wöhler's laboratory. Two of his special friends there were Americans. They were William S. Clark and N. S. Manross, both of whom he was to meet again later in the United States. He returned to Dublin to continue his Trinity course in the winter and spring, and was back in Göttingen the following summer. In that year he was awarded the Ph.D. degree of Göttingen, for a thesis dealing with the chemical examination of a number of ancient Celtic ornaments [7, 8].

It was a striking tribute to Mallet's early scientific training that he could win a Göttingen Ph.D. while still only a Dublin undergraduate. The thesis was remarkable, too, in that, apart from a brief note by Donovan published three years earlier [9], it was the first account of any investigation of the chemical composition of prehistoric Irish materials and objects, including some precious stones, amber and jet, glass beads, and pigments, and even up to the present day it remains the most important single publication on this particular subject.

Although Mallet does not describe the analytical methods that he used, the summations of his quantitative analyses are good, and a few other hints indicate that his work was done with considerable care. His results for the proportions of the principal components of the materials are probably not much inferior to what would be obtained by present-day methods. However, he did not pay much attention to the detection or determination of various minor components, and by the methods then available he could not have achieved results comparable to those which can be obtained by spectrographic and other present-day methods of analysis.

Mallet's interpretations of the chemical significance of his analytical data seem very reasonable and sound, in the view of a leading modern worker in the field of archaeological chemistry, Earle R. Caley of the Ohio State University [10]. The closing words of his memoir clearly indicate his modesty: 'Such are the results of the examination of these antiques so far obtained. It will be seen that some classes of objects in the Academy Museum have not been spoken of at all, and that this investigation is very far from exhausting the subject with respect even to the departments discussed. Conscious of my unfitness for the task, I have left the bearings of these results on archaeology almost untouched; yet the analyses and experiments above described are not, perhaps, absolutely barren in results of interest.'

On leaving Göttingen, Mallet and his friends Clark and Manross were provided with letters of introduction by Wöhler, and toured many of the countries of Europe. They met several of the leading scientists of the day, including Alexander von Humboldt, Heinrich and Gustav Rose, and E. Mitscherlich. In later years, Mallet recalled the qualities of Wöhler both as a teacher and as a director of research. Wöhler always showed great personal kindness to the young Irishman, and long maintained a correspondence with him.

Mallet was first senior moderator and gold medallist in experimental physics at Trinity College in 1853, the year he graduated B.A. By this date, he had a number of independent papers to his name besides those mentioned earlier. One of them dealt with a miniature gold-rush that took place in County Wicklow in 1795 [11], and others dealt chiefly with the chemical examination of foreign and domestic geological specimens [8].

It was almost by accident that Mallet moved permanently to America. In July 1853, his father sent him to the United States to study Ericsson's much-discussed caloric engine. When he arrived, he found that the engine was not working, so he went to visit his Göttingen friend W. S. Clark, who by this time was professor of chemistry at Amherst College, Massachusetts.

Clark persuaded Mallet to stay at Amherst, where he became professor of analytical chemistry in the following year [12]. However, he soon moved to a post as chemist to the state geological survey of Alabama, with headquarters in Tuscaloosa in that state. With this post, Mallet began his lifelong association with the southern states. A further link with the South was forged on 21st July, 1857, by his marriage to Mary Elizabeth Ormond, eldest daughter of a justice of the Alabama supreme court. By the time of his marriage, Mallet was combining his geological post with that of professor of chemistry in the University of Alabama. After a honeymoon in Europe and Ireland, the couple returned to

Tuscaloosa, where their first child, John Ormond, was born the following year.

At this stage, Mallet undertook an exhaustive scientific study of the culture of cotton. Specimens of plants, soils, and rocks from three continents were collected; soils were analysed; and density, cohesion, capillarity, and adsorption of gases were determined. Stems, roots, seeds, and fibres were separately analysed [13].

Shortly afterwards, Mallet moved to a chair of chemistry in the new medical college of Alabama. Provided with funds to buy apparatus, he visited Paris, Darmstadt, and London in 1860, and went to see his parents in Ireland. Except for occasional brief trips abroad, he spent the remainder of his days in the United States, though he never became naturalized. Years later, the fact that he was still a British subject forced cancellation of plans by the United States government to send him as an official commissioner to the Paris Exposition of 1878.

When the American civil war broke out early in 1861, Mallet was at the very centre of things, for the seat of the Confederate government was at Montgomery, Alabama. His sympathies were with his southern friends, and he hastened to join up. He enlisted as a private, but before long was commissioned lieutenant, and made aide-de-camp to General Robert E. Rodes, whom he had known before the war as an engineer working on railway construction [14].

After seeing a period of action, Mallet came to the notice of General (then Colonel) Josiah Gorgas, chief of Confederate ordnance, who had been seeking someone with enough scientific knowledge to supervise the making of small arms and artillery ammunition. He realized that Mallet was just the man he needed, and persuaded him to transfer to ordnance with the rank of captain in May 1862 [15].

Mallet began by bringing into order the almost incredible chaos that existed in the South's ordnance. His originality, sound chemical background, and unusual organizing ability had full scope. He carried out experiments on new types of powder, shells, and rockets, and made plans for the production of percussion caps, friction primers, mineral acids, and other war chemicals. Despite a considerable load of routine work, he found time to invent a new type of shell with polygonal cavities, which burst into a predetermined number of fragments. He was also in advance of his time in perfecting a device for cutting artillery fuzes to set explosion times. He studied the deterioration of gunpowder, and invented a workable substitute for mercury fulminate in percussion caps [16]. The war ended in Southern defeat in 1865, by which time Mallet held the rank of Lieut-Colonel of Artillery.

After the war, Mallet spent some time exploring for oil in Louisiana and Texas, and then accepted the chair of chemistry at the University of Louisiana medical school. In the three years he spent there he devoted much time to the study of medicine, and had the distinction of being awarded an honorary degree of M.D. on leaving the post. Mallet's study of the chemical side of medicine led him in after years to carry out a number of investigations in physiological chemistry and hygiene.

From Louisiana, Mallet moved to the University of Virginia, where he had been asked to teach industrial chemistry. Mallet's is believed to have been the first systematic course in industrial chemistry offered in the United States.

The civil war had interrupted his purely scientific work, but he resumed it as soon as possible afterwards. It would be impossible in this account to list even briefly the wide scope and range of his papers. His scientific publications numbered nearly one hundred [12].

Besides his studies in general and applied chemistry, he devised methods of determining organic matter in drinking waters [17], and added greatly to our knowledge of meteorites and of many unusual ores. Richards has noted that Mallet will be remembered as a chemist chiefly for his pioneer work on the atomic weights of lithium, aluminium, and gold. He writes: 'The work on aluminium was particularly comprehensive and thorough, and has remained our chief basis for a knowledge of this atomic weight ever since its publication in 1880 [18]. . . . The work on lithium, one of the first investigations in a field which has since been very much cultivated in America, was carried out in 1856 [19]. It is interesting to note that this work . . . was far better than that of Stas, as indicated by the most recent investigations of the subject' [20]. Mallet's interest in atomic weights led to his giving a memorial lecture to The Chemical Society in 1892 on the work of J. B. Stas [21].

In 1874, at his father's suggestion, Mallet put his name forward and submitted testimonials as a candidate for the chair of chemistry at Trinity College, Dublin. The chair had become vacant on the death at an advanced age of his old teacher, Apjohn. The chances of Mallet's election without

personal appearance before the authorities were in fact very small, and the successful candidate was J. Emerson Reynolds, who had earlier discovered thiourea in the Royal Dublin Society's laboratory [22].

As Mallet's reputation in science grew with the years, he gave special lecture courses at Johns Hopkins University in 1877 and 1878, and in 1882 won the signal honour of election as president of the American Chemical Society, an organization which he had helped to found six years earlier. His election was a high tribute to a non-American, and to one who had fought on the losing side in the civil war only seventeen years earlier.

In 1882, Mallet was asked to head the chemical faculty of the newly planned University of Texas. His eldest son, John Ormond, was then very ill with tuberculosis, and the move to Texas was made in the hope that the change of climate would do him good. But misfortunes followed fast. The Texas appointment proved unsatisfactory, owing to the delays in getting new buildings constructed and to the slowness of student enrolment [23]. Shortly afterwards, young Mallet died. Mallet moved east to take the chair of chemistry at the Jefferson medical college in Philadelphia. While in transit, all his furniture, books, and other possessions were destroyed in a warehouse fire a few hours before his insurance became effective. The crowning blow was the death of his wife a few months later.

Mallet came back to his old Virginia post, and, except for a brief visit to England and the continent of Europe with his daughter Mary in 1887, remained in Virginia for the remainder of his life. Though he retired in 1908, he received aid from a Carnegie grant and continued to publish research papers. In 1912, he attended an international meeting of chemists in New York, but on 7th November of that year he died at his home at Charlottesville, Virginia.

Mallet was a Fellow of the Royal Society (1877), and was vice-president of The Chemical Society from 1888 to 1890. As an analytical and consulting chemist his services were frequently sought in examining ores, waters, and manufactured goods, and he was often called as an expert medico-legal witness in court cases.

Mallet's American students remembered him as a man of impressive appearance, tall and erect, somewhat stern-visaged; a man who carried himself with distinct poise and dignity [16]. In speaking of his lecture courses, a former student wrote: 'These lectures were a model of precision and continuity. There was no repetition of language or substance, he never hesitated for a word or thought, he was never known to fail or bungle in the least an illustrative experiment he undertook' [24].

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Book reviews

SPECIAL AND GENERAL RELATIVITY

The Theory of Relativity, *by C. Møller. Pp. xii + 386. Clarendon Press, Oxford.* 1952. 35*s. net.*

This is a sound and readable treatise on special and general relativity, leaving out the unified theories of gravitation and electromagnetism, and only briefly touching on cosmology. Its only serious defect is that it is weak, and indeed erroneous, on the historical side. Two striking examples may be mentioned. The FitzGerald contraction, the most outstanding precursor of relativity theory, is attributed to Lorentz (1892) and FitzGerald (1893). Actually, FitzGerald published it in 1892, five months before Lorentz. A still more serious error is the account of the discovery of special relativity. 'Einstein,' says Professor Møller, 'was the first to formulate this new standpoint.' Actually, Poincaré formulated it in 1904 (Einstein took it up in 1905), in a way that has never been improved on. '*Le principe de la relativité*,' he said, '*d'après lequel les lois des phénomènes physiques doivent être les mêmes, soit pour un observateur fixe, soit pour un observateur entraîné dans un mouvement de translation uniforme: de sorte que nous n'avons et ne pouvons avoir aucun moyen de discerner si nous sommes, oui ou non, emportés dans un pareil mouvement*': and he showed that this postulate required '*une mécanique entièrement nouvelle, qui serait surtout caractérisée par ce fait qu'aucune vitesse ne pouvait dépasser celle de la lumière.*' The mathematics needed for this had been discovered in 1903 by Lorentz, who, however, had not enunciated the new physical principle as Poincaré did. E. T. WHITTAKER

DESCARTES' SCIENCE

The Scientific Work of René Descartes (1596–1650), *by J. F. Scott. Pp. viii + 212. Taylor and Francis Limited, London.* 1952. 20*s. net.*

This scholarly work will be of great value to students of the history of science in the seventeenth century. The author, after speaking first of Descartes' early life and briefly surveying his work, proceeds to a detailed account and analysis of the *Discours de la Méthode*, *La Dioptrique*, *Les Météores*, *La Géométrie*, and the *Principia Philosophiae*. It is often supposed that Descartes' contributions to science did not endure, but he was the first to bring the aether into science, by postulating that it had mechanical properties; and the recent theory of Dirac shows that the aether is by no means effete. As to mathematics, a distinguished American mathematician has lately proposed that secondary schools should drop pure geometry altogether, and teach the properties of space from the beginning on Cartesian lines. E. T. WHITTAKER

ALCHEMY AND ALCHEMISTS

The Alchemists, *by F. Sherwood Taylor. Pp. 246, with numerous figures and plates. W. Heinemann Limited, London.* 1951. 12*s.* 6*d. net.*

This book, printed by the Replika process from an American edition, gives what is probably the best account of the personalities and ideas of alchemy which is available. It opens with the remote sources in some statements by Aristotle and the practical arts of Egyptian craftsmen, and then gives a very interesting account of the earliest texts, in Greek, dating from the first centuries A.D. but probably based on earlier material. These contain practical information, including what is probably the first description of distillation, which operation seems to have moulded alchemical ideas. Some long extracts from Zosimos give his interesting 'visions,' which have attracted the attention of psychologists recently. This section is authoritative and most valuable. After a short chapter on Chinese alchemy (which is at least as old as that in the Greek texts and is different in character), the chapter on alchemy in Islam gives an intelligible account of the views of Jabir. The views of Kraus on this elusive personality are stated, with the proviso that they are not accepted by all authorities. The progress of alchemy in Europe, beginning in the twelfth century with translations from Arabic works, is well described, with extracts from the sources. Alchemical symbolism is a difficult subject, but the author does his best to make its meaning intelligible, and he then deals with some circumstantial accounts of transmutations given by esteemed authors, concluding that they have no real foundation in fact. The period of transition from alchemy to chemistry as seen in technical works and in the writings of Paracelsus is sketched; in this part the great importance of van Helmont is unaccountably not emphasized. Alchemy was a many-sided study from the first, and included what was called the Hermetic philosophy, which such writers as Francis Bacon realized was an aspect of thought worthy of consideration. It is difficult to set out its tenets, which reached into the sphere of religion, but Sherwood Taylor has given much thought to this part of his subject and his views are clearly stated. This is altogether a most interesting and thoughtful book which can be read not only by chemists but by the general reader, since the story is told in a non-technical manner, yet with so much detail that it is also a book for the expert. The production of the book is worthy of its contents. J. R. PARTINGTON

GAS ANALYSIS

Traité de Manipulation et d'Analyse des Gaz, *by H. Guérin, with a preface by P. Lebeau. Pp. 635, with 310 figures. Masson et Cie, Paris.* 1952. 5100 *fr.*

This very interesting work begins with a short history of gasometric methods and a general bibliography. The remainder is divided into four parts of roughly equal importance. The first deals with the manipulation of gases—preparation, conservation, measurement of volumes, and so on. The second describes general methods of gas analysis by such means as combustion, physical separation methods, and the determination of the constants of mixtures. In the third part are reviewed a number of specific gases, from hydrogen to free radicals. Finally, the author deals with certain practical applications, for example in analysing the products of the combustion and gasification of solids, in the petroleum industry, and in metallurgy. The work concludes with author and subject indexes. All the material is clearly presented and the style is excellent.

Guérin has performed a valuable service in putting at the disposal of research workers so clear and complete an exposition of techniques which are of great practical importance, but of which there has been no recent comprehensive account, especially in French. His treatise typifies the thorough and critical spirit of French scholars, and seems to us perfectly to fulfil the author's aim.

JEAN TIMMERMANS

REVIEW OF NUCLEAR SCIENCE

Annual Review of Nuclear Science, Vol. I. *Pp.* x + 645. *Annual Reviews, Inc., Stanford, Cal., in co-operation with the National Research Council of the National Academy of Science.* 1952. $6 *net.*

During the last six years there has been an outburst of research in the field of nuclear science, and publications have been still further increased by the release of much information obtained during the war, when the work was, of necessity, kept secret. Nuclear science has also, since the war, enjoyed exceptional financial support in the U.S.A. and other countries, and this has not only provided a further stimulus to work in the field but has tended to widen its definition to include as many subjects as possible.

This 'Annual Review of Nuclear Science' is the first volume of a new series sponsored by the committee on nuclear science of the U.S. National Research Council, though responsibility for its publication and that of subsequent volumes has been taken over by Annual Reviews Inc., of Stanford, California, who regularly produce similar volumes in other scientific fields.

The present volume contains twenty-six articles by authoritative writers, covering a wide assortment of topics in the nuclear science field, such as meson physics, high-energy accelerators (five articles), isotopic tracers in chemistry and biochemistry, geochemistry, and biological effects of radiation. Subsequent volumes will contain articles on other topics in the field. Volume I covers work published during 1950, but each article also attempts to include sufficient background material to make the advances during the year under review capable of critical appreciation. Each article concludes with a list of references to the literature cited, and there is a general index at the end containing the names of some 3000 authors. A high proportion of the references is to the American literature, and the articles vary in style between those that merely catalogue published work and those that are more critical essays on the topic in question. The volume is well produced and is commendably free from misprints. Together with its successors in the series, it will form a useful, though not exhaustive, summary of progress in this field of science. M. W. PERRIN

NITROGENOUS HETEROCYCLIC COMPOUNDS

Heterocyclic Compounds. *Edited by Robert C. Elderfield. Volumes III and IV. Pp.* 442 *and* 674. *John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 96*s. and* 136*s. net.*

These two books give an account of some of the most important nitrogenous heterocyclic compounds. Volume III is devoted mainly to indoles and their related compounds (P. L. Julian, E. W. Meyer, and H. C. Printy), and to a much smaller extent to *iso*indole (R. C. Elderfield and T. N. Dodd), carbazole (W. Freudenberg), pyrindine, quinindine, and related compounds (R. C. Elderfield and E. T. Losin), and bicyclic systems with a nitrogen atom common to both rings (H. R. Ing). More than half of volume IV is occupied by a 343-page conspectus of quinoline (R. C. Elderfield), the remainder containing surveys of *iso*quinoline (W. J. Gensler), acridines (A. Albert), phenanthridine (L. P. Walls), and benzoquinolines (L. P. Walls). These names guarantee that the articles are authoritative and accurate, and one can only marvel at, and be grateful for, the industry and care which have been bestowed on the books by men whose time is so fully occupied by heavy research commitments. The results are completely satisfactory. Each review is comprehensive without claiming to be exhaustive, and includes all the main features of the subject together with the necessary significant detail. There is always the danger that books of this type may be disconnected and incoherent. It can be stated at once that this has been avoided by unobtrusive but skilful and effective editing, and the result is a connected, lucid, and readable (in the best sense of that misused word) text.

As in so many American textbooks, the printing and formulae are excellent, and the publishers are to be congratulated on using small type only for references, thereby making each page a delight to the eye and a pleasure to read. The books will be invaluable to research workers, teachers, and students, and no chemical library will be complete without them.

NEIL CAMPBELL

PROBLEMS OF LIFE

Problems of Life: an Evaluation of Modern Biological Thought, *by Ludwig von Bertalanffy. Pp.* 216. *Watts and Company, London.* 1952. 25*s. net.*

The need for examining nature and knowledge as a whole in the light of biology is painfully obvious to those who see the results of examining it in relative shadow. The opposing schools of vitalism and mere non-vitalism (or mechanism) have not, however, had much to offer us, and some time ago they came to a standstill. To start something moving has been in the past the object of many thoughtful biologists, such as J. S. Haldane, J. H. Woodger, J. Needham, and E. S. Russell. All have tried to give the organism a place of its own in nature, perhaps a half-way house between its old stations.

The author of the present book, Ludwig von Bertalanffy, sees himself as the mainspring of this movement for the last twenty years. He represents a view of life which is founded on physiology, the connecting link between inanimate matter and the higher world of the spirit. It is, he claims, a 'synthesis' of the two old systems. How exactly he synthesizes the principle of divergence from beginnings (implied by mechanism) with that of convergence on ends (implied by vitalism), is passed over with a grand gesture or a little paradox, with quotations of what he said in his last book, or with references to what he will say in his next.

It may be claimed that von Bertalanffy describes clearly how the life of the individual works. The hierarchies of Woodger still make an agreeable scholastic exercise—but when we descend to earth after the exercise, and look round, we find that we are where we started. We have explained nothing. We see the healthy individual living. But why is he like that? What are his relations with other individuals? What are their origin? Why do some succeed and others fail?

These great questions are of the essence when we try to connect life with the rest of nature. They belong, however, not to physiology, but to genetics. For this reason, no doubt, Bertalanffy fills the middle of his book with genetics. He has evidently read a great deal about genetics—but it was a long time ago and he has not understood what it meant. Partly, this is due to his formalistic outlook. Laws and even theories to him are solid bodies. They sometimes lie in organisms. And they also reproduce. He is able to tell us what the third Mendelian law was (p. 72). He is also able to tell us on one page that 'all laws of nature are of a statistical nature' (p. 172), and on another page that 'evolution is the product of chance, and therein obeys no law' (p. 92).

von Bertalanffy has written a somewhat worse book than any of his predecessors in the same school. This is because in twenty years the tide of biology has risen and washed away what should have been his foundations. And he has not noticed what was happening. C. D. DARLINGTON

CHEMICAL HISTORY OF THE ELEMENTS

Man and the Chemical Elements, *by J. Newton Friend. Pp.* 354. *Charles Griffin and Company, London.* 1951. 27*s.* 6*d. net.*

Of this book, two things may be said with certainty: that the author enjoyed writing it, and that those who turn its pages will enjoy reading it. It is a pleasantly discursive, gossipy book: Pliny would have loved it. Not that the author has Pliny's uncritical credulity, but he has a *penchant* for the oddities of knowledge and cannot resist a good story. If he sees an inviting byway, he does not hesitate to explore it, and we are quite ready to follow him—especially as he leads us back to the high road sooner or later. The theme of the book is when and how the various chemical elements were discovered, and the narrative is embellished with choice morsels accumulated by the author in the course of a lifetime's reading of ancient and modern chemical literature. Uses and properties of the elements are given where they are of general interest, and the story as a whole ranges from the Stone Age to the present day.

A book of this kind, perfect as a chemist's bedside book, must not be scrutinized with too critical an eye. Some of Dr Friend's statements are open to question, and there are occasional errors of fact. To emphasize minor blemishes, however, would be to show base ingratitude to one who has spent so much time and labour in compiling a delightful book for our delectation. E. J. HOLMYARD

PAPER CHROMATOGRAPHY

A Guide to Filter Paper and Cellulose Powder Chromatography, *by J. N. Balston and B. E. Talbot, edited by Tudor S. G. Jones. Pp.* 145, *with several half-tone illustrations. H. Reeve Angel and Company Limited, London, and W. and R. Balston Limited, Maidstone.* 1952. 8*s. net.*

Paper Chromatography; a Laboratory Manual, *by R. J. Block, R. LeStrange, and G. Zweig. Pp.* x + 195, *with two colour plates and several half-tone and line illustrations. Academic Press Inc., New York; Academic Books Limited, London.* 1952. 36*s. net.*

These two books are appropriately reviewed together, for they cover much the same ground and cater for the same kind of reader, namely the chemist who wants to know how far, and in what way, paper chromatography can be applied to his own practical problems.

As is to be expected, the books have much in common. Both deal, from the practical viewpoint, with techniques of separating various classes of substances, both organic and inorganic, on paper. In each book will be found sufficient practical details for experimental work to be started at once with some confidence, and literature references for pursuing the finer details.

While both books have their defects, the work by Balston, Talbot, and Jones is to be preferred. It is better written, broader and more scholarly in its treatment, has a larger bibliography, and, except in respect of binding, is the better produced and the better printed.

Both books may be criticized for the extreme weakness of discussion of work carried out before 1934. Block, LeStrange, and Zweig are doubtless correct in saying that the present popularity of paper chromatography stems from its brilliant application by Martin and his co-workers, but this is no reason at all for concluding that earlier work, so unfortunately overlooked, no longer deserves attention; in point of fact the very extensive earlier literature well repays (though seldom obtains) careful study. Both books, again, are rather weak on the theoretical treatment.

It is vexatious to see the American book advertised on the dust-cover as the first on the subject, although the British one in fact appeared some months earlier. While this lapse may be accounted for by the normal time of passage through the press, it certainly does not excuse the injustice done to Friedrich Cramer. His important work on paper chromatography is not even mentioned, although the authors claim in their foreword to cite literature up to at least 1st January, 1952, and to some extent beyond. Cramer's book was published at the end of 1951, reprinted from *Angewandte Chemie.*

The British work contains several valuable features which are absent from, or very superficially treated, in its American counterpart. There is, for example, a section, with a bibliography of nineteen references, on the very important technique of using radioactive tracers; of this Block, LeStrange, and Zweig say no more than that 'numerous applications for this technique seem assured.' There is, too, a detailed discussion of the nature of various types of filter-paper, which is, of course, of the most fundamental importance possible in this type of analysis. Further, it deals also with the closely allied field of separation on cellulose powder. When these notable advantages, with others already noted, are set against the fact that the British publication, inferior only in binding, sells at eight shillings compared with thirty-six for the American, chemists have an obvious choice before them.

TREVOR I. WILLIAMS

ELECTRONIC COLLISIONS

Electronic and Ionic Impact Phenomena, *by H. S. W. Massey and E. H. S. Burhop. Pp. xviii* + 654. *Oxford University Press, London.* 1952. 70*s. net.*

This book is, in effect, a companion volume to the well-known study of Massey and Mott of the theory of atomic collisions, for in the new book the necessary theories are only outlined, and the reader is referred for detail to the earlier volume. The first half of the book is devoted to the interaction of electrons with matter. An extensive survey of the scattering of electrons by gases is followed by studies of electronic collisions with molecules and with surfaces, and of collisions involving radiation. The second half covers atomic collisions. Chapters are devoted to atomic collisions under gas kinetic conditions; collisions of positive ions and neutral atoms with surfaces; and recombination.

The scope of the book, therefore, is fundamental and far-reaching. The authors have sifted a considerable mass of experimental evidence, and have presented the results in a concise form. One of the most valuable features of the book is its collection of tables of cross-sections, which summarize results throughout. A dominant impression in the later chapters, on ionic collisions, is the degree of disagreement between experimentalists; most of the evidence is pre-war, and it would seem that post-war physicists have not made use of recent advances in technique to clear up many uncertainties in this field. As regards choice of material, some subjects, such as ionization by fast nuclear particles, are rather surprisingly omitted. On the other hand, a number of interesting sidelines are touched on.

The standard of publication is, as usual with the Oxford University Press, very high. W. D. ALLEN

Some books received

(*Note.* Mention of a book on this page does not preclude subsequent review.)

BIOCHEMISTRY

Lipid Metabolism, *edited by R. T. Williams. Biochemical Society Symposia No. 9. Pp.* 102. *Cambridge University Press, London.* 1952. 13*s. net.*

BIOLOGY

Biology, its Human Applications, *by Garrett Hardin. Second edition. Pp.* 720, *with half-tone and line illustrations. W. H. Freeman and Company, San Francisco, California; Bailey Bros. and Swinfen Limited, London.* 1952. 42*s.* 6*d. net.*

The Epigenetics of Birds, *by C. H. Waddington. Pp.* 272, *with line illustrations. Cambridge University Press, London.* 1952. 35*s.* net.

General Genetics, *by Adrian M. Srb and Ray D. Owen. Pp.* 561, *with half-tone and line illustrations. W. H. Freeman and Company, San Francisco, California; Bailey Bros. and Swinfen Limited, London.* 1952. 47*s. net.*

BOTANY

Materiae Vegetabiles, *Vol. I, No.* 1, *edited by C. Regel and Fr. Tobler. Pp.* 128. *Dr W. Junk, The Hague.* 1952. *Quarterly. Per annum,* 40 *Dutch guilders net.*

The Molecular Architecture of Plant Cell Walls, *by R. D. Preston. Pp.* 211, *with line and half-tone illustrations. Chapman and Hall Limited, London.* 1952. 36*s. net.*

Morphogenesis in Plants, *by C. W. Wardlaw. Pp.* 176, *with line illustrations. Methuen and Company Limited, London.* 1952. 10*s.* 6*d. net.*

La Vie des Fruits, *by R. Ulrich. Pp.* 365, *with line and half-tone illustrations. Masson et Cie, Paris.* 1952. 2000 *fr.*

CHEMISTRY

Modern Aspects of Inorganic Chemistry, *by H. J. Emeléus and J. S. Anderson. Revised edition. Pp.* 557, *with line diagrams. Routledge and Kegan Paul Limited, London.* 1952. 35*s. net.*

Modern Chemical Processes, *by the editors of 'Industrial and Engineering Chemistry.' Volume II. Pp.* 299, *with line and half-tone diagrams. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1952. 40*s. net.*

Organic Chemistry, *by E. E. Turner and Margaret M. Harris. Pp.* 904. *Longmans, Green and Company Limited, London.* 1952. 50*s. net.*

The Physical Chemistry of Surface Films, *by W. D. Harkins. Pp.* 413, *with illustrative graphs. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1952. 80*s. net.*

La Synthèse Protéique, *by Émile F. Terroine. Pp.* 539. *Centre National de la Recherche Scientifique, Paris.* 1952. 3200 *fr.*

GENERAL SCIENCE

Ballistics in the Seventeenth Century, *by A. R. Hall. Pp.* 186. *Cambridge University Press, London.* 1952. 21*s. net.*

Color in Business, Science and Industry, *by D. B. Judd. Pp.* 401, *with diagrams and graphs. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 52*s. net.*

Food and Population and Development of Food Industries in India. *Pp.* 357. *Central Food Technological Research Institute, Mysore.* 1952. 10*s. net.*

Food Science, a Symposium on Quality and Preservation of Foods, *edited by E. C. Bate-Smith and T. N. Morris. Pp.* 319, *with line and half-tone illustrations. Cambridge University Press, London.* 1952. 40*s. net.*

Statistical Tables and Formulas, *by A. Hald. Pp.* 97. *John Wiley and Sons Incorporated, New York; Chapman and Hall Limited, London.* 1952. 20*s. net.*

Statistical Theory with Engineering Applications, *by A. Hald. Pp.* 783. *John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 72*s. net.*

Stereo Photography in Practice, *by E. F. Linssen. Pp.* 326, *with line diagrams. The Fountain Press, London.* 1952. 42*s. net.*

GEOLOGY

Sir Douglas Mawson Anniversary Volume, *edited by M. F. Glaessner and E. A. Rudd. Pp.* 224, *with line diagrams. The University of Adelaide, Adelaide.* 1952. 30*s.* (*Aust.*) *net.*

Rocks for Chemists, *by S. J. Shand. Pp.* 146, *with* 32 *half-tone plates. Thomas Murby and Company, London.* 1952. 21*s. net.*

INDUSTRY

Atmospheric Pollution: Its Origin and Prevention, *by A. R. Meetham. Pp.* 268, *with line and half-tone illustrations. Pergamon Press Limited, London.* 1952. 35*s. net.*

Reviews of Petroleum Technology, *Vol.* 12 (*covering* 1950). *Pp.* 513. *Institute of Petroleum, London.* 1952. 50*s. post free.*

MEDICINE

The Story of the Adaptation Syndrome, *by Hans Selye. Pp.* 225, *with line diagrams. Acta Incorporated, Montreal.* 1952. $4.50 *net.*

METALLURGY

Metallurgical Equilibrium Diagrams, *by W. Hume-Rothery, J. W. Christian, and W. B. Pearson. Pp.* 311, *with half-tone and line illustrations. The Institute of Physics, London.* 1952. 50*s. net.*

PHYSICS

Basic Methods in Transfer Problems, *by V. Kourganoff. Pp.* 281. *Oxford University Press, London.* 1952. 35*s. net.*

The Initiation and Growth of Explosions in Liquids and Solids, *by F. P. Bowden and A. D. Yoffe. Pp.* 104, *with line and half-tone illustrations. Cambridge University Press, London.* 1952. 22*s.* 6*d. net.*

Detonation in Condensed Explosives, *by J. Taylor. Pp.* 196, *with line and half-tone illustrations. Oxford University Press, London.* 1952. 25*s. net.*

Imperfections in Nearly Perfect Crystals, *edited by W. Shockley, J. H. Hollomon, R. Maurer, and F. Seitz. Pp.* 490, *with half-tone and line illustrations. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 60*s. net.*

Philosophic Problems of Nuclear Science. *Eight lectures by Werner Heisenberg* (*translated by F. C. Hayes*). *Pp.* 126. *Faber and Faber Limited, London.* 1952. 16*s. net.*

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Theory of Electric Polarization, *by C. J. F. Böttcher. Pp.* 492. *Elsevier Publishing Company, Amsterdam; Cleaver-Hume Press Limited, London.* 1952. 70*s. net.*

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Traité de Zoologie. Anatomie, Systématique, Biologie. *Volume I—Phylogénie, Protozoaires: Généralités, Flagellés. Published under the direction of Pierre-P. Grassé. Pp.* 1071, *with line and half-tone illustrations. Masson et Cie, Paris.* 1952. *Paper covers* 9000 *fr., bound* 9600 *fr.*

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ENDEAVOUR

The British quarterly scientific review ENDEAVOUR was first published in January 1942. Its purpose was to enable men of science, and particularly British men of science, to speak to the world in an hour when not only nations but the internationalism of science suffered the dangers of warfare. For the better fulfilment of this purpose ENDEAVOUR was from the first published in four separate editions—English, French, Spanish, and German. An Italian edition has been published since January 1948. Today the situation is happily different, but there can be no lasting peace without full and sincere co-operation between nations in every realm of human enterprise. In the scientific field ENDEAVOUR can thus play as useful a part in peace as it did in war, and for this reason the decision has been taken to make its publication permanent.

ENDEAVOUR is distributed without charge to senior scientists, scientific institutions, and libraries throughout the world, the guiding principle being that of helping scientists overseas to maintain those contacts which their British colleagues have always so much valued. Within these limits the Editors are at all times glad to consider the addition of new names to the mailing list.

Made and printed in Great Britain at THE KYNOCH PRESS, *Witton, Birmingham, 6, for the publishers,*
IMPERIAL CHEMICAL INDUSTRIES LIMITED, *London, S.W.1*

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von Bertalanffy has written a somewhat worse book than any of his predecessors in the same school. This is because in twenty years the tide of biology has risen and washed away what should have been his foundations. And he has not noticed what was happening. C. D. DARLINGTON

CHEMICAL HISTORY OF THE ELEMENTS

Man and the Chemical Elements, *by J. Newton Friend. Pp.* 354. *Charles Griffin and Company, London.* 1951. 27*s.* 6*d. net.*

Of this book, two things may be said with certainty: that the author enjoyed writing it, and that those who turn its pages will enjoy reading it. It is a pleasantly discursive, gossipy book: Pliny would have loved it. Not that the author has Pliny's uncritical credulity, but he has a *penchant* for the oddities of knowledge and cannot resist a good story. If he sees an inviting byway, he does not hesitate to explore it, and we are quite ready to follow him—especially as he leads us back to the high road sooner or later. The theme of the book is when and how the various chemical elements were discovered, and the narrative is embellished with choice morsels accumulated by the author in the course of a lifetime's reading of ancient and modern chemical literature. Uses and properties of the elements are given where they are of general interest, and the story as a whole ranges from the Stone Age to the present day.

A book of this kind, perfect as a chemist's bedside book, must not be scrutinized with too critical an eye. Some of Dr Friend's statements are open to question, and there are occasional errors of fact. To emphasize minor blemishes, however, would be to show base ingratitude to one who has spent so much time and labour in compiling a delightful book for our delectation. E. J. HOLMYARD

PAPER CHROMATOGRAPHY

A Guide to Filter Paper and Cellulose Powder Chromatography, *by J. N. Balston and B. E. Talbot, edited by Tudor S. G. Jones. Pp.* 145, *with several half-tone illustrations. H. Reeve Angel and Company Limited, London, and W. and R. Balston Limited, Maidstone.* 1952. 8*s. net.*

Paper Chromatography; a Laboratory Manual, *by R. J. Block, R. LeStrange, and G. Zweig. Pp.* x + 195, *with two colour plates and several half-tone and line illustrations. Academic Press Inc., New York; Academic Books Limited, London.* 1952. 36*s. net.*

These two books are appropriately reviewed together, for they cover much the same ground and cater for the same kind of reader, namely the chemist who wants to know how far, and in what way, paper chromatography can be applied to his own practical problems.

As is to be expected, the books have much in common. Both deal, from the practical viewpoint, with techniques of separating various classes of substances, both organic and inorganic, on paper. In each book will be found sufficient practical details for experimental work to be started at once with some confidence, and literature references for pursuing the finer details.

While both books have their defects, the work by Balston, Talbot, and Jones is to be preferred. It is better written, broader and more scholarly in its treatment, has a larger bibliography, and, except in respect of binding, is the better produced and the better printed.

Both books may be criticized for the extreme weakness of discussion of work carried out before 1934. Block, LeStrange, and Zweig are doubtless correct in saying that the present popularity of paper chromatography stems from its brilliant application by Martin and his co-workers, but this is no reason at all for concluding that earlier work, so unfortunately overlooked, no longer deserves attention; in point of fact the very extensive earlier literature well repays (though seldom obtains) careful study. Both books, again, are rather weak on the theoretical treatment.

It is vexatious to see the American book advertised on the dust-cover as the first on the subject, although the British one in fact appeared some months earlier. While this lapse may be accounted for by the normal time of passage through the press, it certainly does not excuse the injustice done to Friedrich Cramer. His important work on paper chromatography is not even mentioned, although the authors claim in their foreword to cite literature up to at least 1st January, 1952, and to some extent beyond. Cramer's book was published at the end of 1951, reprinted from *Angewandte Chemie.*

The British work contains several valuable features which are absent from, or very superficially treated, in its American counterpart. There is, for example, a section, with a bibliography of nineteen references, on the very important technique of using radioactive tracers; of this Block, LeStrange, and Zweig say no more than that 'numerous applications for this technique seem assured.' There is, too, a detailed discussion of the nature of various types of filter-paper, which is, of course, of the most fundamental importance possible in this type of analysis. Further, it deals also with the closely allied field of separation on cellulose powder. When these notable advantages, with others already noted, are set against the fact that the British publication, inferior only in binding, sells at eight shillings compared with thirty-six for the American, chemists have an obvious choice before them.

TREVOR I. WILLIAMS

ELECTRONIC COLLISIONS

Electronic and Ionic Impact Phenomena, *by H. S. W. Massey and E. H. S. Burhop. Pp. xviii* + 654. *Oxford University Press, London.* 1952. 70*s. net.*

This book is, in effect, a companion volume to the well-known study of Massey and Mott of the theory of atomic collisions, for in the new book the necessary theories are only outlined, and the reader is referred for detail to the earlier volume. The first half of the book is devoted to the interaction of electrons with matter. An extensive survey of the scattering of electrons by gases is followed by studies of electronic collisions with molecules and with surfaces, and of collisions involving radiation. The second half covers atomic collisions. Chapters are devoted to atomic collisions under gas kinetic conditions; collisions of positive ions and neutral atoms with surfaces; and recombination.

The scope of the book, therefore, is fundamental and far-reaching. The authors have sifted a considerable mass of experimental evidence, and have presented the results in a concise form. One of the most valuable features of the book is its collection of tables of cross-sections, which summarize results throughout. A dominant impression in the later chapters, on ionic collisions, is the degree of disagreement between experimentalists; most of the evidence is pre-war, and it would seem that post-war physicists have not made use of recent advances in technique to clear up many uncertainties in this field. As regards choice of material, some subjects, such as ionization by fast nuclear particles, are rather surprisingly omitted. On the other hand, a number of interesting sidelines are touched on.

The standard of publication is, as usual with the Oxford University Press, very high. W. D. ALLEN

Some books received

(*Note.* Mention of a book on this page does not preclude subsequent review.)

BIOCHEMISTRY

Lipid Metabolism, *edited by R. T. Williams. Biochemical Society Symposia No. 9. Pp.* 102. *Cambridge University Press, London.* 1952. 13*s. net.*

BIOLOGY

Biology, its Human Applications, *by Garrett Hardin. Second edition. Pp.* 720, *with half-tone and line illustrations. W. H. Freeman and Company, San Francisco, California; Bailey Bros. and Swinfen Limited, London.* 1952. 42*s.* 6*d. net.*

The Epigenetics of Birds, *by C. H. Waddington. Pp.* 272, *with line illustrations. Cambridge University Press, London.* 1952. 35*s.* net.

General Genetics, *by Adrian M. Srb and Ray D. Owen. Pp.* 561, *with half-tone and line illustrations. W. H. Freeman and Company, San Francisco, California; Bailey Bros. and Swinfen Limited, London.* 1952. 47*s. net.*

BOTANY

Materiae Vegetabiles, *Vol. I, No.* 1, *edited by C. Regel and Fr. Tobler. Pp.* 128. *Dr W. Junk, The Hague.* 1952. *Quarterly. Per annum,* 40 *Dutch guilders net.*

The Molecular Architecture of Plant Cell Walls, *by R. D. Preston. Pp.* 211, *with line and half-tone illustrations. Chapman and Hall Limited, London.* 1952. 36*s. net.*

Morphogenesis in Plants, *by C. W. Wardlaw. Pp.* 176, *with line illustrations. Methuen and Company Limited, London.* 1952. 10*s.* 6*d. net.*

La Vie des Fruits, *by R. Ulrich. Pp.* 365, *with line and half-tone illustrations. Masson et Cie, Paris.* 1952. 2000 *fr.*

CHEMISTRY

Modern Aspects of Inorganic Chemistry, *by H. J. Emeléus and J. S. Anderson. Revised edition. Pp.* 557, *with line diagrams. Routledge and Kegan Paul Limited, London.* 1952. 35*s. net.*

Modern Chemical Processes, *by the editors of 'Industrial and Engineering Chemistry.' Volume II. Pp.* 299, *with line and half-tone diagrams. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1952. 40*s. net.*

Organic Chemistry, *by E. E. Turner and Margaret M. Harris. Pp.* 904. *Longmans, Green and Company Limited, London.* 1952. 50*s. net.*

The Physical Chemistry of Surface Films, *by W. D. Harkins. Pp.* 413, *with illustrative graphs. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1952. 80*s. net.*

La Synthèse Protéique, *by Émile F. Terroine. Pp.* 539. *Centre National de la Recherche Scientifique, Paris.* 1952. 3200 *fr.*

GENERAL SCIENCE

Ballistics in the Seventeenth Century, *by A. R. Hall. Pp.* 186. *Cambridge University Press, London.* 1952. 21*s. net.*

Color in Business, Science and Industry, *by D. B. Judd. Pp.* 401, *with diagrams and graphs. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 52*s. net.*

Food and Population and Development of Food Industries in India. *Pp.* 357. *Central Food Technological Research Institute, Mysore.* 1952. 10*s. net.*

Food Science, a Symposium on Quality and Preservation of Foods, *edited by E. C. Bate-Smith and T. N. Morris. Pp.* 319, *with line and half-tone illustrations. Cambridge University Press, London.* 1952. 40*s. net.*

Statistical Tables and Formulas, *by A. Hald. Pp.* 97. *John Wiley and Sons Incorporated, New York; Chapman and Hall Limited, London.* 1952. 20*s. net.*

Statistical Theory with Engineering Applications, *by A. Hald. Pp.* 783. *John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1952. 72*s. net.*

Stereo Photography in Practice, *by E. F. Linssen. Pp.* 326, *with line diagrams. The Fountain Press, London.* 1952. 42*s. net.*

GEOLOGY

Sir Douglas Mawson Anniversary Volume, *edited by M. F. Glaessner and E. A. Rudd. Pp.* 224, *with line diagrams. The University of Adelaide, Adelaide.* 1952. 30*s.* (*Aust.*) *net.*

Rocks for Chemists, *by S. J. Shand. Pp.* 146, *with* 32 *half-tone plates. Thomas Murby and Company, London.* 1952. 21*s. net.*

INDUSTRY

Atmospheric Pollution: Its Origin and Prevention, *by A. R. Meetham. Pp.* 268, *with line and half-tone illustrations. Pergamon Press Limited, London.* 1952. 35*s. net.*

Reviews of Petroleum Technology, *Vol.* 12 (*covering* 1950). *Pp.* 513. *Institute of Petroleum, London.* 1952. 50*s. post free.*

MEDICINE

The Story of the Adaptation Syndrome, *by Hans Selye. Pp.* 225, *with line diagrams. Acta Incorporated, Montreal.* 1952. $4.50 *net.*

METALLURGY

Metallurgical Equilibrium Diagrams, *by W. Hume-Rothery, J. W. Christian, and W. B. Pearson. Pp.* 311, *with half-tone and line illustrations. The Institute of Physics, London.* 1952. 50*s. net.*

PHYSICS

Basic Methods in Transfer Problems, *by V. Kourganoff. Pp.* 281. *Oxford University Press, London.* 1952. 35*s. net.*

The Initiation and Growth of Explosions in Liquids and Solids, *by F. P. Bowden and A. D. Yoffe. Pp.* 104, *with line and half-tone illustrations. Cambridge University Press, London.* 1952. 22*s.* 6*d. net.*

Detonation in Condensed Explosives, *by J. Taylor. Pp.* 196, *with line and half-tone illustrations. Oxford University Press, London.* 1952. 25*s. net.*

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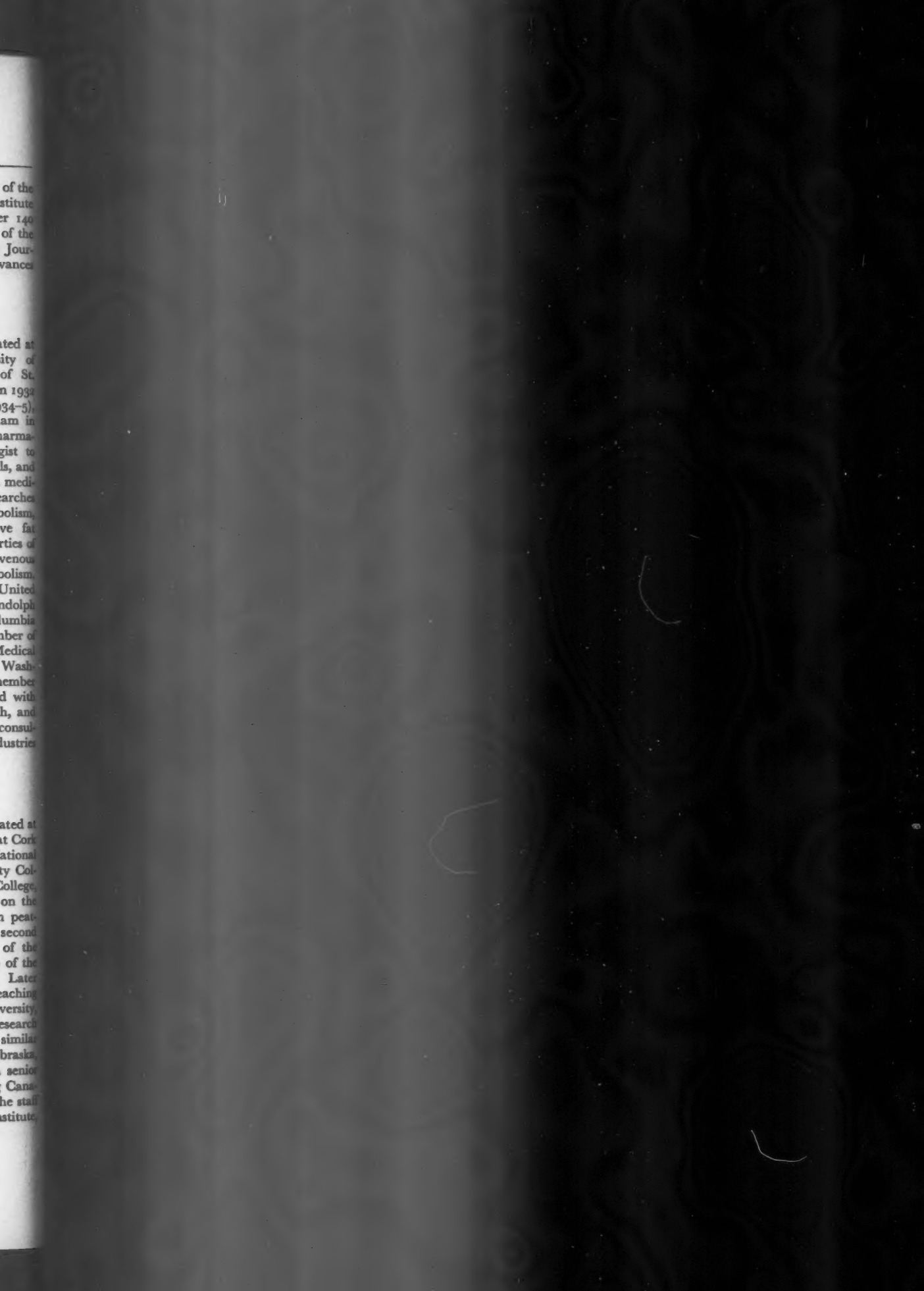
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